Improving Vaccination Coverage in an Adult Ambulatory Rheumatology Clinic through a Quality Improvement Process

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Abstract

Patients with autoimmune rheumatic diseases are at high risk for infections. Currently 6 vaccines are recommended by the Advisory Council on Immunization Practices for routine immunization of immunocompromised adults in the United States: influenza, tetanus/diphtheria/pertussis, herpes zoster, human papilloma virus, and two pneumococcal vaccines. Levels of vaccination coverage for all adults in the United States are below target; paradoxically, despite their increased susceptibility to infection and risk of complications, the levels of vaccination coverage for patients with immune mediated inflammatory diseases are even lower than in the general population. A quality improvement project was conducted in order to overcome system barriers and improve influenza and pneumococcal vaccination coverage in this vulnerable population.

Keywords: Vaccination, Quality Improvement, Autoimmune, Rheumatology, Immunosuppressed

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Section One: Nature of the Problem

Introduction to the Problem

Vaccines are underutilized in the United States adult population (Centers for Disease Control and Prevention, 2018; Heyman et al., 2008), including in rheumatology clinics (Curtis et al., 2010; Yun et al., 2016). Having worked in such a setting for over 19 years, the author has seen far too many patients with compromised immune systems suffer with complications from vaccine-preventable illnesses such as influenza and pneumonia. In addition to the personal and professional feelings of regret and responsibility that are experienced by health care providers when patients have less than optimal outcomes, there is also a significant financial burden that comes with these illnesses which can be measured in the billions of dollars annually (Ozawa et al., 2016). Various researchers have studied and identified reasons for missed opportunities for vaccination in patients with rheumatic diseases (Johnson et al., 2008; Kimoto et al., 2016; Sandler et al., 2014; Taddio et al., 2012; Zimmerman et al., 2003). Many methods have been utilized in an attempt to overcome barriers to vaccination in healthy adults (Dexter et al., 2004; A. X. Garg et al., 2005; Kiefe et al., 2001; Milkman et al., 2011; Nichol, 1998; Stone et al., 2002; Szilagyi et al., 2000) as well as immunocompromised adults (Baker et al., 2016; Bays et al., 2015, 2016; Sonali P. Desai et al., 2013; Dudley et al., 2014; S. Garg et al., 2016, 2018; Kimoto et al., 2016; Ledwich et al., 2009; Schoenfeld et al., 2014; Sheth et al., 2017). This project proposed to increase vaccination coverage in an adult rheumatology clinic by identifying and overcoming systems barriers to vaccination.

Purpose of the Project

According to the Centers for Disease Control and Prevention (CDC), there are over 5 million adults in the United States living with rheumatoid arthritis, psoriatic arthritis, or ankylosing spondylitis (Center for Disease Control and Prevention (CDC) & National Health and Nutrition Examination Survey Data, 2019). Another 320,000 have definite or probable systemic lupus erythematosus (Centers for

Disease Control and Prevention (CDC), 2018), and there are many more individuals diagnosed with the less common rheumatic diseases such as vasculitis, mixed connective tissue disease, autoimmune myopathies, systemic sclerosis, and Sjögren's Syndrome. These patients, due to the nature of their diseases as well as the immunosuppressant medications that are often prescribed for them, are at higher risk for infection and complications from infection than the general population and therefore are sorely in need of protection from communicable diseases (Listing et al., 2013; Müller-Ladner & Müller-Ladner, 2013; Rubin et al., 2014).

Currently six vaccines are recommended by the Advisory Council on Immunization Practices (ACIP) for routine immunization of immunocompromised adults in the United States: influenza, tetanus/diphtheria/pertussis (TDaP), herpes zoster, human papilloma virus, and two different pneumococcal vaccines (Advisory Committee on Immunization Practices, 2019). These recommendations differ from those for healthy adults in that certain vaccines (measles, mumps, rubella, varicella) are not recommended because they are live attenuated, whereas other vaccines (pneumococcal polysaccharide, pneumococcal conjugate) are recommended at a younger age. Levels of vaccination coverage for all adults in the United States are below target (National Vaccine Program Office, 2019); paradoxically, despite their increased susceptibility to infection and risk of complications, the levels of vaccination coverage for patients with immune mediated inflammatory diseases (IMIDs) are even lower than in the general population (Curtis et al., 2010; Yun et al., 2016). From 1999-2006, only 33% of eligible patients with rheumatoid arthritis and psoriatic arthritis in a study that examined nearly 150,000 patients from the Medicare Chronic Conditions Warehouse received pneumococcal vaccines, and only 20% received influenza vaccines all five years of the study (Curtis et al., 2010).

The cost of this lack of protection is shared by all members of society in terms of actual dollars spent as well as utilization of finite healthcare resources. In terms of finances, the burden of vaccine-preventable illness in the United States is high (Ozawa et al., 2016). The economic burden for influenza in the United States in 2015 was $5.79 billion and for pneumococcal disease it was $1.86 billion (Ozawa et al., 2016). While it is true that not all of these costs were incurred by patients with IMIDs, clearly they represent a target population for intervention. Besides the economic burden, these barriers also have an impact on the quality of healthcare as proposed by the National Academy of Medicine (Institute of Medicine (US) Committee on Quality of Health Care in America, 2001). Some of the barriers identified in the literature, such as fear of side effects and belief by patients that they do not need immunization, may be overcome simply with patient education and are not intrinsically part of the process that results in lower quality of care. Other barriers, however, can be directly related to quality outcomes. A selection is presented in Table 1. The relationship of these barriers to each of the six domains of healthcare quality put into perspective just how far-reaching one intervention (or lack thereof) can be for an individual as well as a healthcare system.

The objective of this DNP quality improvement (QI) project was to increase vaccination coverage in immunosuppressed patients. The process through which this objective was accomplished was the implementation of interventions to overcome systems barriers to vaccination in an adult ambulatory rheumatology clinic. Outcomes were measured in terms of changes to the percent of patients up to date on vaccinations over predetermined time periods.

Table 1: Examples of Barriers to Vaccination and How They Affect Healthcare Quality

Domain	Barrier	Relationship
Patient safety	Knowledge gaps	Providers cannot deliver safe care if they are unaware of guidelines
Effective	Lack of processes	Haphazard approach leads to missed opportunities and lack of efficacy
Patient-centered	Lack of time	Provider lack of time results in possible harm to patient
Timely	Missing records	Having to collect records can cause a delay in vaccination
	Lack of reminders	Missing window of opportunity for time-sensitive vaccines can result in decreased efficacy
Efficient	Vaccine not stocked	Increases burden to patient to have to make >1 trip
Equitable	Cost to patient	Patients with insurance coverage or funds to pay for vaccines receive higher quality care than patients without coverage/funds.

Note: The National Academy of Medicine proposed the six domains of health care quality in order to guide development initiatives and for all stakeholder to be better able to understand the relevance of quality (Agency for Healthcare Research and Quality, 2018). This table takes some of the commonly reported barriers to vaccination and relates them to quality domains.

Section Two: Review of the Literature

There is an abundance of literature related to the topic of QI in immunizations. Interventions to improve vaccination coverage range from patient-focused to provider-focused, rudimentary to high-tech, directed towards pediatric or adult patients, and many other approaches and variations. The literature search for this project was crafted to provide results which were timely and relevant. Results were then carefully evaluated in order to identify publications that were scientifically grounded, relevant to the investigator’s target population, and reproducible in the proposed setting.

Clinical practice problem statement

In adult patients on immunosuppressive medications seen in an outpatient rheumatology clinic (P), how do prepopulated orders attached to care gap alerts in the EMR, a team approach, and optimization of workflow using a centralized notification board (I) compared to individual provider practice (C) affect levels of vaccination coverage (O)?

Evaluation/Summary of the evidence from the literature

Literature searches of PubMed, Cochrane, and Scopus were performed using the following search terms in various combinations: vaccine, rheumatic disease, barriers, quality improvement, and immunosuppressed. Several limits were applied including human-only, full text available, English language, and, in PubMed, limit to last 10 years. Thirty-five additional records were found via a search of the American College of Rheumatology (ACR) website using the same search terms with the exception of rheumatic disease; this search was limited to the last 10 years.

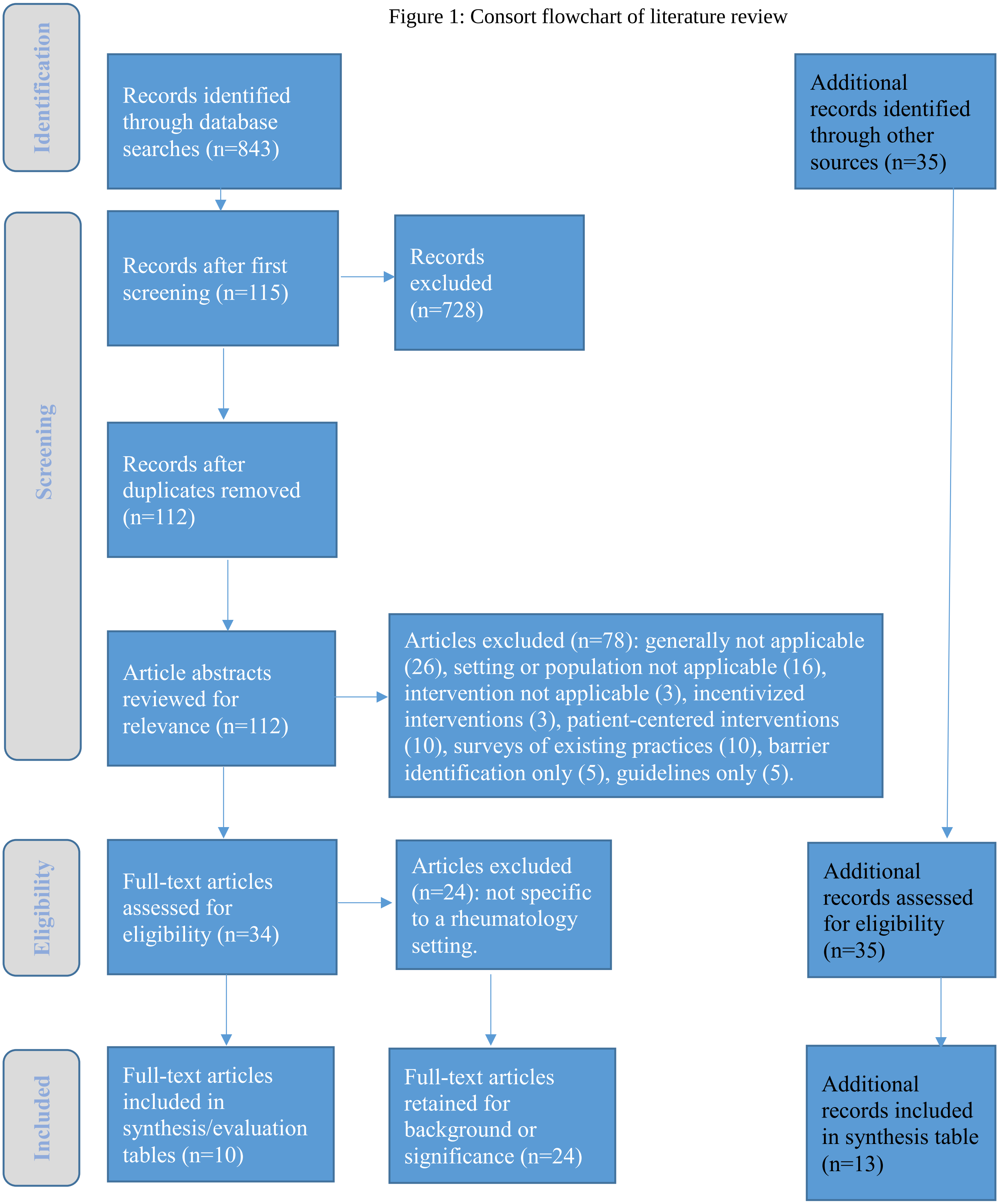
Identification

The first stage of the literature search resulted in 843 citations: PubMed 663 articles, Cochrane Library 134 articles, Scopus 46 articles.

Screening

Based on their titles alone, 126 out of 134 Cochrane results were immediately deemed irrelevant and discarded. Nine of the 46 Scopus results appeared to be applicable based on their titles and abstracts. 97 of the original 663 PubMed results survived the first screening round. 115 entries in total were entered into an Excel Spreadsheet (Appendix F). Three duplicate entries were removed, leaving 112. The abstracts for the remaining 112 articles were reviewed; 34 were deemed relevant enough to warrant further investigation. The other articles were discarded for various reasons as detailed in a Consort flowchart (Figure 1).

Figure 1: Consort flowchart of literature review



Thirty-four full-text articles and all 35 additional records were reviewed for eligibility. Of these, 24 articles were found to be relevant in terms of basic QI processes but were not specific to a rheumatology or immune-mediated inflammatory disease setting. These 24 articles were retained for background and significance reasons but were not assessed via synthesis or evaluation tables. 13 additional records were relevant in terms of the current project.

Included

A total of ten journal articles that were deemed to be appropriate and relevant were identified through this literature search (Baker et al., 2016; Chow & Shojania, 2017; S. P. Desai et al., 2011; Sonali P. Desai et al., 2013; S. Garg et al., 2018; Harris et al., 2015; Karr et al., 2016; Ledwich et al., 2009; Parker et al., 2013; Sheth et al., 2017). In addition 13 abstracts from ACR annual meetings held between 2012 and 2018 were selected by the author for inclusion in a synthesis table (Aguirre et al., 2017; Bays et al., 2015, 2016; Bussey & Ostrowski, 2014; S. Desai et al., 2012; Dudley et al., 2014; S. Garg et al., 2016; Goodson et al., 2018; Margaretten et al., 2015; O'Brien & Schmidt, 2017; Ostrowski & Chaudhry, 2016; Schoenfeld et al., 2014; Swee et al., 2018). The 10 articles are summarized in the evaluation and synthesis tables (Appendices A and B); the 13 ACR abstracts are summarized in a synthesis table (Appendix C).

Critical appraisal of the evidence

The ten articles included in the evaluation table all advanced through the first several rounds of narrowing down the literature search; a deeper reading of each article revealed strengths and weaknesses in each.

The quality of the evidence was evaluated using a rapid critical appraisal (RCA) tool (Melnyk & Fineout-Overholt, 2015) and was found to be excellent in all 10 articles. The few lapses in quality that were identified were mostly due to gaps in data collection or analysis. Even these gaps provided a learning experience for the reviewer; knowing that other practitioners had problems with EMR queries provided advance notice of how to structure future queries in such a way that certain subsets of patients are not missed. Another area for improvement gleaned from the evidence was how to handle vaccination prompts that were ignored or bypassed by clinicians. During one project (Sheth et al., 2017), over 40% of the alerts that were fired by the EMR were bypassed by the physician seeing the patient. Had the project been designed differently, those dismissed alerts could have provided an opportunity to reeducate providers in real time in order to improve the vaccination process.

Some of the major points that stand out from the evaluation and synthesis tables are that projects utilizing at least two of the three interventions (use of EMR, process change, team approach) resulted in more positive results. Interventions that used only one type of intervention had the lowest increases in vaccination.

Presentation of theoretical basis

As immunizations fall under the domain of public health, it is appropriate to base a QI project that attempts to improve vaccination coverage on a public health theoretical model. One such model is the Health Belief Model (HBM), which was developed in the 1950s by social psychologists from the US PHS, including Irwin Rosenstock, Godfrey Hochbaum, Stephen Kegeles, and Howard Leventhal. It is one of the oldest, most well-known, and most widely used health behavior theories. It was originally developed to try to determine why free, public tuberculosis screening efforts were failing. The creators of the model believed that providers can’t convince the public to change their health behaviors until they understand why individuals behave the way they do (Irwin M. Rosenstock, 2005).

The main assumption of the HBM is that individuals act when they perceive a threat to their personal health and when they have the conviction that the benefits of health-promoting activities will outweigh the expense of following through with the action (I. M. Rosenstock et al., 1988). For this project the HBM was adapted slightly in that it is modification of the behaviors of the clinicians, not patients, which is the objective.

There are four original constructs of the HBM: perceived severity, perceived susceptibility, perceived benefits, and perceived barriers (I. M. Rosenstock et al., 1988). Examples of each construct in terms of vaccination are shown in Table 2. Both the traditional (patient) and adapted (provider) perspectives are shown in the table, illustrating how the constructs can act as motivation to act for each group.

It is not enough for a QI project to be grounded in a proven theoretical framework; it must also conform to the overall mission of the setting in which the project takes place. The mission statement of the large Midwestern academic medical center where this project took place is “To provide better care of the sick, investigation in their problems and further education of those who serve.” By exploring why providers fail to protect their patients through immunization, and overcoming those barriers through EBP, this project fulfilled all three parts of the institute’s mission.

Table 2: Application of the Health Belief Model

	Patient	Provider
Perceived Severity	How bad is the illness? Can it kill me?	How bad is the illness? Could the patient become severely ill? Could this illness kill this patient?
Perceived Susceptibility	How common (or rare) is the illness? Can I really catch it?	Are we in a high-incidence area? Is my patient planning on traveling to an endemic area? Does this patient work in a high-risk setting? What medications is my patient on that could make him or her more susceptible to this illness?
Perceived Benefits	How effective is the vaccine? Will I be protected? Will I be protecting others?	What are the efficacy rates? What medications might affect efficacy? Even if the vaccine is not 100% effective, will my patient benefit in terms of lower morbidity?
Perceived Barriers	Will my insurance cover it? How badly will it hurt? Will it make me sick?	I don’t have time to get into a risk/benefit discussion with every patient/find the MA. My patient doesn’t have time to wait. Will insurance cover it? Are there medical contraindications? This EMR is a pain to figure out – there are too many options!

Utility/Feasibility

Improving vaccination coverage in immunosuppressed patients is not only applicable in the rheumatology setting, it is a professional imperative. Patients come to rheumatology with derangements of their immune systems. Simply having an IMID puts them at higher risk for infection. The medications that are used to attempt to control IMIDs are immunomodulators and immunosuppressants; in effect, rheumatology providers take immunologically vulnerable patients and make them more vulnerable. There is a professional duty to protect these patients from infectious diseases whenever possible. However, if protecting patients in this way were easy, it would already be happening and there would be no need for a QI project. Any immunization project has financial costs and costs in terms of time utilization, and this project was no exception. One cost that did not have to be considered was the cost of the vaccines themselves; they were already stocked regularly and built into the department budget. Billing for the vaccines and administration was already set up in the EMR. The costs of having a pharmD on the QI team were also already accounted for, as the Department of Pharmacy provides a full time pharmacist to the department. One of the goals of having an embedded pharmacist is participation in QI projects, therefore her time and expertise were already covered financially. Time involvement is a major consideration; physicians and advanced practice provider (APPs) are granted 10% protected time in which to do projects such as these, but the medical assistants (MA) had no such flexibility in their schedules. Pulling them away from clinic in order to help design this or any QI project was a cost to consider, as the MAs not directly involved with the planning of the project had to room their patients, assist with procedures, and otherwise cover for them.

Due to the existing infrastructure and the fact that this project was geared towards increasing the use of materials which were already considered standards of care (SOC), it was anticipated that the overall financial cost of this project would be low. A proposed budget (Table 5) and timeline (Figure 5) are presented in Section 3.

Recommendations summary

According to the literature, the most successful intervention by far is organizational change; in the meta-analysis mentioned above, the odds ratio of the effectiveness of organizational change for improvement of vaccine uptake was 16.0 (Stone et al., 2002). The components of organizational change mentioned in the meta-analysis and other studies include standing orders, the establishment of prevention clinics, and designation of specific prevention responsibilities to non-provider staff (Bays et al., 2016; Bridges et al., 2015; Nichol, 1998; Stone et al., 2002). Provider education, but not provider feedback, was also found to be modestly effective (Bays et al., 2016; Bridges et al., 2015). Patient reminders are only modestly successful in improving vaccination uptake in adults according to a Cochrane Review (Jacobson Vann et al., 2018), but another systematic review found increases in vaccination rates of 5-20% in patients who received any type of reminder or recall intervention (Szilagyi et al., 2000).

Similar to what the evidence shows for success in intervention type, the most successful intervention feature for improving immunization coverage is collaboration and teamwork. The adjusted odds ratio of this feature was 17.9; the next highest feature on the list was “high visual appeal and clarity” (of materials used during the intervention), which had an adjusted odds ratio of 3.25 (Stone et al., 2002). While still a statistically significant increased effect, it is clear that teamwork provides a much higher yield in terms of improvement of vaccination coverage.

The strongest recommendations gleaned from the literature review are as follows:

- Use a team-based approach (S. Garg et al., 2018; Harris et al., 2015)
- Streamline workflow (Sonali P. Desai et al., 2013; S. Garg et al., 2016; Sheth et al., 2017)
- Utilize orders attached to an alert in the EMR (Baker et al., 2016; Karr et al., 2016; Ledwich et al., 2009; Sheth et al., 2017)

The key stakeholders in this provider-based intervention were the rheumatology providers (physicians and APPs) and the MAs who administer vaccines. The department IT analyst’s expertise on the implementation of Care Gap Alerts (CGAs) in the existing EMR made her a key stakeholder as well. The main strategy to engage the key stakeholders was a presentation made by the author at a monthly staff meeting. This presentation included the baseline levels of vaccine coverage, the consequences of vaccine preventable illnesses, an overview of the immunization CGA, and an explanation of the new process to alert MAs that a vaccine has been ordered (the whiteboard).

Potential barriers included provider resistance to having to address a CGA during a 20 minute follow up visit, provider confusion regarding safety and timing of vaccines, confusion over the new workflow, and MA reluctance to change the vaccination process. Strategies to address these barriers included appealing to providers’ sense of duty to protect a vulnerable population, emphasizing that spending the time to prevent infections would likely save a much greater amount of time spent dealing with an illness in the future, making the process as easy as possible, reminding providers that the rheumatology pharmacist is always on site to answer any questions about vaccine appropriateness, and illustrating to the MAs that the new process was more centralized than the current process.

Section Three: Methods

Recommendations for implementation of practice change

As seen in the evaluation and synthesis tables, many methods have been utilized in an attempt to overcome barriers to vaccination. In addition, a meta-analysis published in 2002 reviewed, categorized and distilled data covering 83 different interventions from 29 trials to that date and made clear, hierarchical, evidenced-based recommendations for clinical use (Stone et al., 2002). These recommendations are borne out by the more recent evidence gathered for this project.

Barriers to vaccination which were identified in outpatient rheumatology clinics include provider knowledge gaps, missing records, lack of reminders, lack of time, lack of processes of care that facilitate immunization, fear of side effects, vaccine not stocked, absence of recommendation by provider, costs, lack of vaccine requirements for adults, and belief by patients that they do not need immunizations (Bridges et al., 2015; Dudley et al., 2014; Gannon et al., 2012; S. Garg et al., 2016; Johnson et al., 2008; Sandler et al., 2014).

According to the literature reviewed for this project, four main factors contribute to the problem of low levels of vaccination coverage in an ambulatory specialty clinic: individual (the ordering and administrating clinicians), patient, organizational (systems for identifying eligible patients), and task (procedures for ordering and administrating vaccines). Many conditions may contribute to missed opportunities for vaccination including lack of time, lack of space (exam rooms), and lack of actual vaccine. The areas that afforded the greatest opportunity for improvement were the focus of this QI project: individual, systems, and task.

Plan for implementation of the EBP practice change

Practice Setting

The setting for this project was the Main Campus location of the outpatient rheumatology department of a large Midwestern hospital. Approximately 500 patients with a variety of rheumatic and immunologic diseases are seen in this department per week. All patients with these diseases who are on immunosuppressive treatment are at risk both for contracting and experiencing higher rates of complications from vaccine-preventable diseases such as influenza and community acquired pneumonia (Listing et al., 2013; Müller-Ladner & Müller-Ladner, 2013; Rubin et al., 2014). These types of patients are similar or the same as those from the cited studies examining levels of vaccination coverage and opportunities for improving them. Vaccinations for influenza and pneumonia were already routinely stocked in the department and all members of the clinical team were familiar with their storage and administration.

The facts that a) this patient population is in need of vaccinations, b) vaccinations are available and part of the standard of care, c) levels of vaccine coverage are below target, and d) recommendations for interventions in similar types of patients exist made this setting appropriate for the proposed quality improvement project.

Readiness for Change

Many stakeholders were affected by the practice changes of the QI project. Medical assistants were asked to change their workflow; providers' workflow in the EMR and after the visit were altered. The rheumatology department's readiness to change was assessed using the New Idea Scorecard (Fraser, 2019) (Appendix D). The core group of six stakeholders completed the assessment. There was broad agreement across all attributes and interventions. The majority of interventions received scores of 4 ("change is strong relative to this attribute") or 5 ("change is very strong relative to this attribute"). This was not the case for the intervention of "documentation", which was given a score of 3 for many attributes by most of the stakeholders. Further discussion revealed that what "documentation" meant was unclear to the stakeholders. After it was explained that documentation will be attached to the CGA (for ordering) and unchanged (for administration), all stakeholders welcomed the change and felt it would be accepted by the department.

Summary of the Plan

In order to improve vaccination coverage in an outpatient clinic, the baseline rates must be known. The first step is to decide which records to include in the analysis. The recommendations from ACIP are not disease-specific; rather, they are based on immunosuppression. As part of the feasibility assessment of the project the author submitted a request to the institution's information technology division (ITD) to query the EMR. The gatekeeper to data is the application analyst. She fields all requests for database mining and assesses them for appropriateness to clinical care while also checking for any possible patient privacy concerns. This query identified patients seen in the adult rheumatology clinic between 9/1/2017 and 8/31/2018 who were prescribed disease modifying antirheumatic drugs, both traditional (DMARD) and biologic (bDMARD) (Table 3).

Table 3: Medications included in baseline query

Medication (DMARD)	Medication (bDMARD)	Medication (small molecule)
Azathioprine	Abatacept	Baricitinib
Cyclophosphamide	Adalimumab	Tofacitinib
Leflunomide	Anakinra	
Methotrexate	Belimumab	
Mycophenolate Mofetil	Certolizumab	
Prednisone	Etanercept	
	Golimumab	
	Infliximab	
	Rituximab	
	Sarilumab	
	Secukinumab	
	Tocilizumab	
	Ustekinumab	

The EMR database was then instructed to take this master list of immunosuppressed rheumatology patients and search for records of influenza, TDaP, herpes zoster recombinant, pneumococcal conjugate, and pneumococcal polysaccharide vaccinations (Table 4).

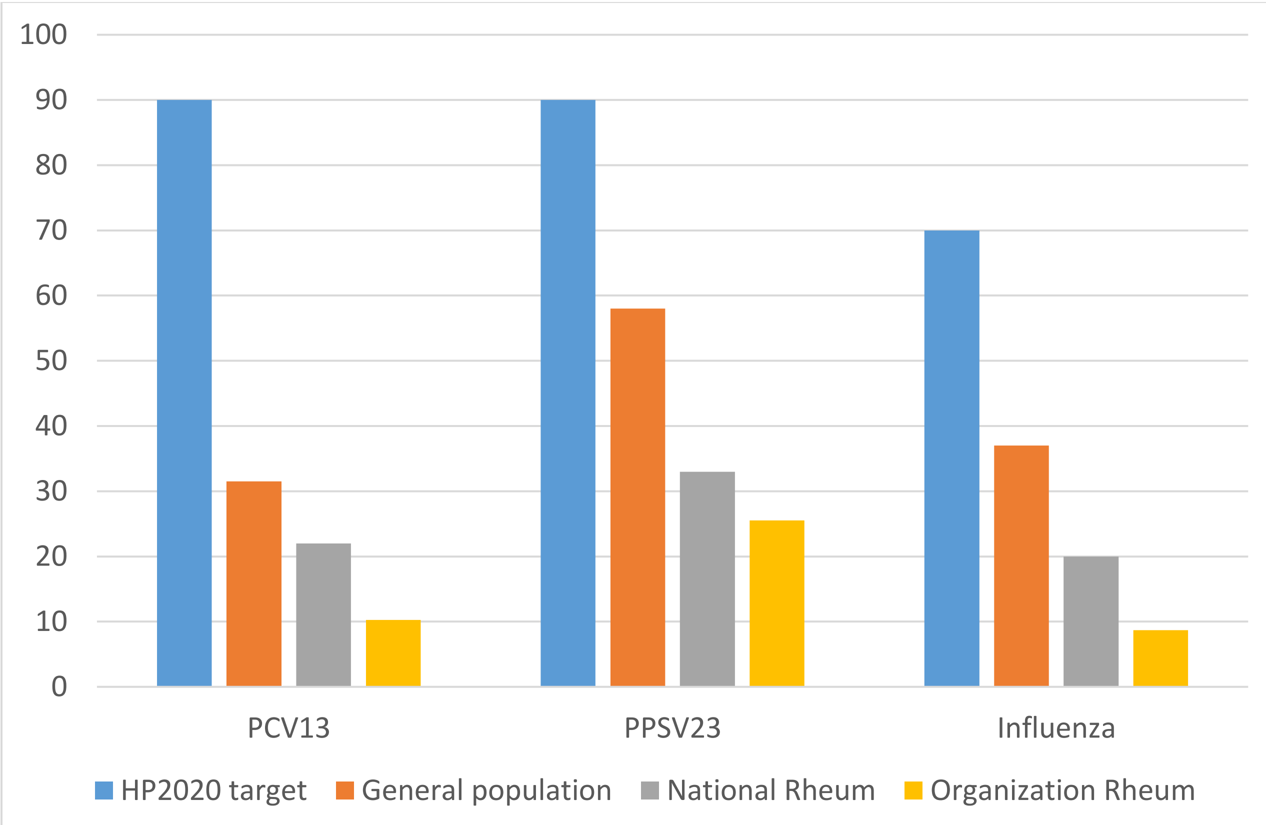
Table 4: Vaccinations and parameters included in baseline query

Vaccines	Visit parameters
Influenza (High Dose Influenza Vaccine, or Influenza Virus Split) Pneumococcal-13 (PCV-13, Prevnar™) Pneumococcal-23 (PPSV 23, Pneumovax™) Tdap (TDAP vaccine age 7+ IM, Adacel™) Zoster vaccine recombinant, IM (Shingrix™) Zoster vaccine live, sub-Q (Zostavax™)	Main Campus Adult Rheumatology Outpatient Clinic Sept 1, 2017 – Aug 31, 2018

These data were provided to the author in a spreadsheet, which was then stored on a secure drive. One vaccine, zoster recombinant, only recently became available and has not been studied for either safety or efficacy in patients with autoimmune disease; therefore the rates for zoster vaccine were collected, but were not included in the intervention at this time. Another vaccine, human papilloma virus (HPV), was approved in 2018 for adults up to age 45 (U.S. Food & Drug Administration, 2018); because this approval was so new at the time of this project and there are many unknowns related to cost, insurance coverage, and use in adult patients on immunosuppressive medications, HPV vaccination was also not included. Finally, although TDaP vaccination rates were collected, there is no nationally recognized benchmark for TDaP coverage. With no established benchmark to measure against, TDaP was deemed inappropriate for a QI project. The three ACIP-recommended vaccines that remained and included in the QI project were influenza, PCV-13, and PPSV-23.

An evaluation of baseline levels of vaccination coverage in the proposed study site revealed that for the one year period that was studied, coverage was well below targets. Healthy People 2020 calls for 70% coverage for influenza and 90% coverage for pneumonia (Offices of Disease Prevention and Health Promotion, 2019a). The rates for all patients who fit the query criteria were PCV-13 10.3%, PPSV-23 25.5%, and influenza 8.7% (Figure 2). Appendix E breaks down vaccination coverage by medication used.

Figure 2: Baseline Vaccine Data



After determining the baseline rates of vaccination for patients on immunosuppressive medications, the next step was to continue planning the change by deciding on an intervention. As described above, the strongest recommendations gleaned from the literature review are to use a team-based approach, streamline workflow, and utilize orders attached to an alert in the EMR, typically via a best practice alert (BPA). A BPA is a tool within the EMR that notifies clinicians when they need to tend to an important task. Once a BPA fires, it must be actively addressed or dismissed in order to continue working in the patient's record.

In order to follow the recommendation from the literature of utilization of alerts and orders in the EMR, a scheduled institution-wide upgrade that coincided with the QI project was taken advantage of. While the new version of the institution's EMR does not incorporate BPAs, it does utilize care gap alerts (CGAs) which are similar in many important ways. CGAs, like BPAs, are automatically launched on the home screen once a patient record is opened. In addition, CGAs, like BPAs containing order sets, have a prepopulated order attached meaning the provider does not have to complete a separate task to order a vaccine after opening the CGA. One restriction that is inherent to CGAs compared to BPAs is that the CGAs currently in use at the project site are not modifiable; they only launch when an intervention is appropriate based on preset guidelines that do not, at this time, include immunosuppression. This factor does not alter the utility of CGAs for alerting providers to the need for influenza vaccine, since this vaccine is recommended for all adults by ACIP. However, pneumonia vaccines are universally recommended only for adults 65 years of age and older. Since these recommendations would not be tailored to meet the ACIP recommendations for immunosuppressed patients, CGAs were not part of the QI project plan for pneumonia vaccination. Based on this evidence and the inherent restrictions in the institution's EMR, this QI project utilized an existing CGA coupled with the use of workflow optimization for influenza vaccines, and workflow optimization alone for pneumonia vaccines.

The other two of the three recommendations were achieved by building a small core team of two physicians, two APPs, and two MAs in order to address current workflow issues. This team met on three occasions to discuss problems with the current vaccination process and brainstorm ideas for how to make it work better for all team members. Prior to this project, the methods for a provider to notify an MA that a vaccine was needed were to either hang a tag from the door flags, page the MA, or walk around the department looking for the MA. All team members agreed that the hanging tags were the most convenient for the provider but the least convenient for the MA and the least efficient for the patient; if the MA was in an exam room in another hallway rooming patients, it could take 15-20 minutes before she happened to walk down the hall where the tags were hanging. Paging the MA was disruptive to the workflow, as MAs are assigned to 3-5 providers each day and room patients and assist with joint injections. Walking around looking for the MA was obviously frustrating and time-consuming for the provider.

The proposed new workflow involved installation of 2 whiteboards on either end of the centralized nurse's station, which connects the two exam room hallways in the department. After the provider was done seeing the patient, he or she wrote down the vaccine and room number on the whiteboard. Any available MA was then responsible for administering the vaccine. The previous and proposed workflows are outlined in figures 3 and 4. After the new workflow was decided upon, a timeline was presented to the Department Chair and part of the monthly staff meeting was allotted for presentation of the project to all members of the department.

Figure 3: Current Provider Workflow

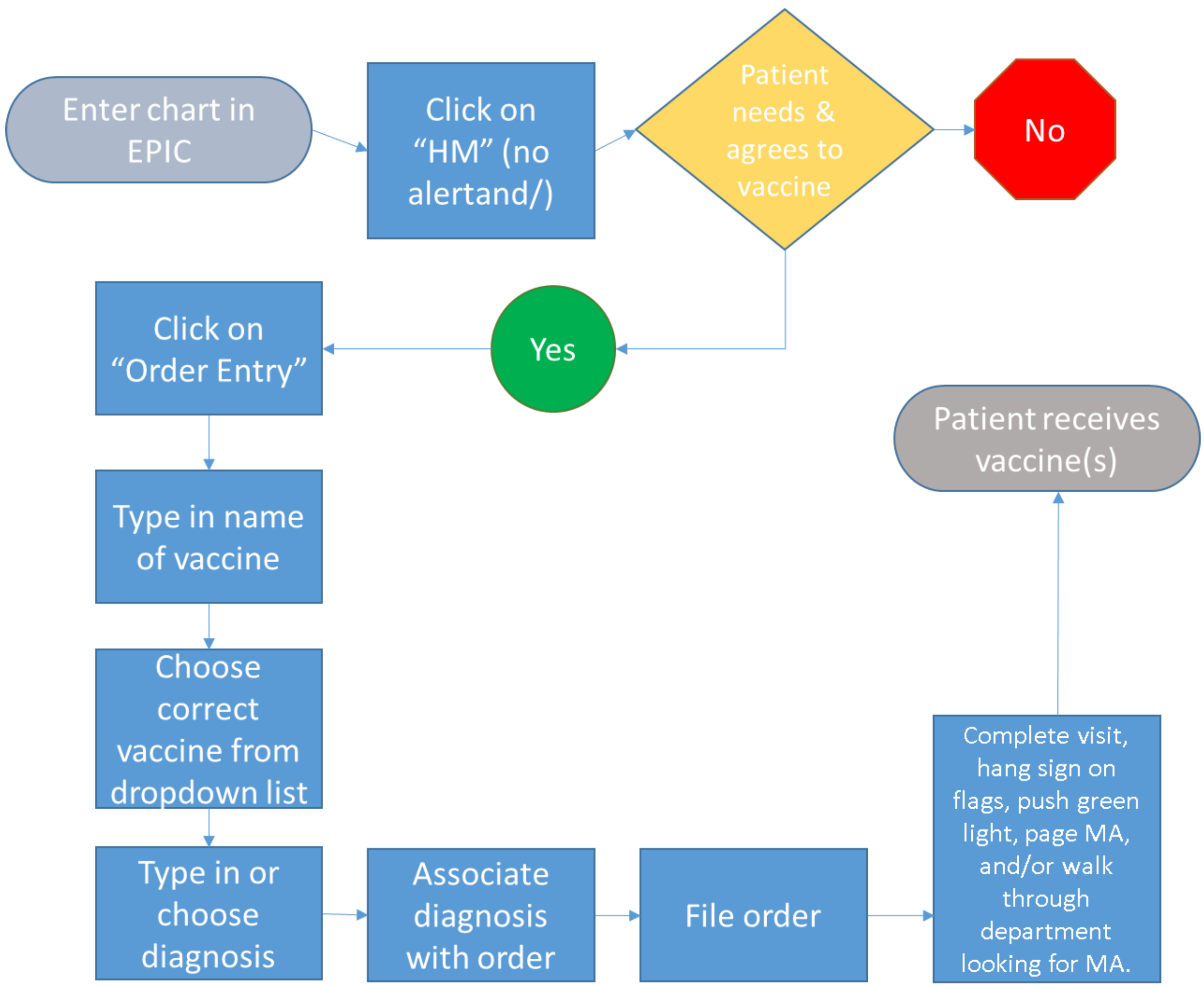
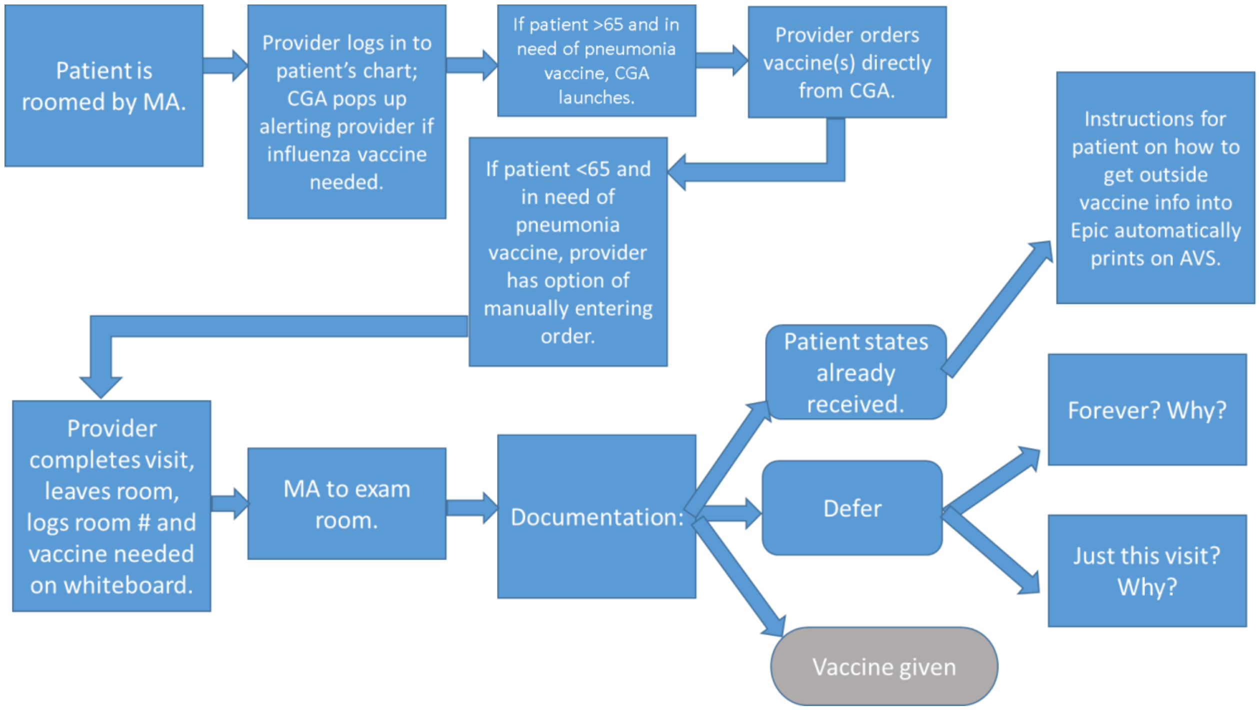


Figure 4: Proposed Workflow



The go-live date for the hospital-wide EMR upgrade was in early November, which was coincidentally the same week as the American College of Rheumatology annual meeting. Almost all providers attended the meeting and were not on campus for the go-live. Therefore, the whiteboards were installed and ready to use the week after the EMR upgrade, when the rheumatology department was again fully staffed.

At weeks 4, 8, and 12 after launch, the same terms/parameters that were used for baseline data gathering (with the exception of the date range) were used by the ITD analyst to request vaccination data for patients seen during the previous 4 weeks.

Measurement Methods

Outcomes measurement

An increase in vaccination coverage was chosen as the indicator that the QI project was successful. While the bar set by Healthy People 2020 was the ultimate goal, any improvement in the number of patients up to date on vaccinations over the course of this project was welcomed. An improvement of only 10% over 12 weeks signifies that hundreds more immunosuppressed patients were protected from influenza and pneumonia compared to the time prior to the interventions.

Instruments used

Baseline vaccination coverage levels were compared to Healthy People 2020 targets as well as each of the 3 monthly intervals.

Why this measure is appropriate

Healthy People 2020 establishes benchmark goals for many conditions, diseases, and preventive measures. It is a collaboration between several federal agencies with scientific expertise in relevant fields (Offices of Disease Prevention and Health Promotion, 2019b). The goals for influenza and pneumococcal vaccination are well-established and therefore appropriate goals for this project.

Data collection process

As explained above, the gatekeeper to data is the application analyst. Given that the application analyst fields requests from an entire institute and is also responsible for training coordination, her time is very limited. It was anticipated that this would be a major barrier to data collection for the project. Despite scheduling meetings as far in advance as possible and being aware of major EMR upgrades and downtimes, this limitation did prove to be significant and it took several weeks to receive query results from the database team.

Data analysis plan

Given that the data analysis consisted of a simple pre- and post-intervention comparison, it was not anticipated that complex statistical analyses would be needed for this project. Once vaccination coverage rates were collected, the percentage change was compared to baseline and HP2020 benchmarks in order to determine if the new processes should remain in place or if further interventions were necessary.

Proposed budget, time, and resources plan

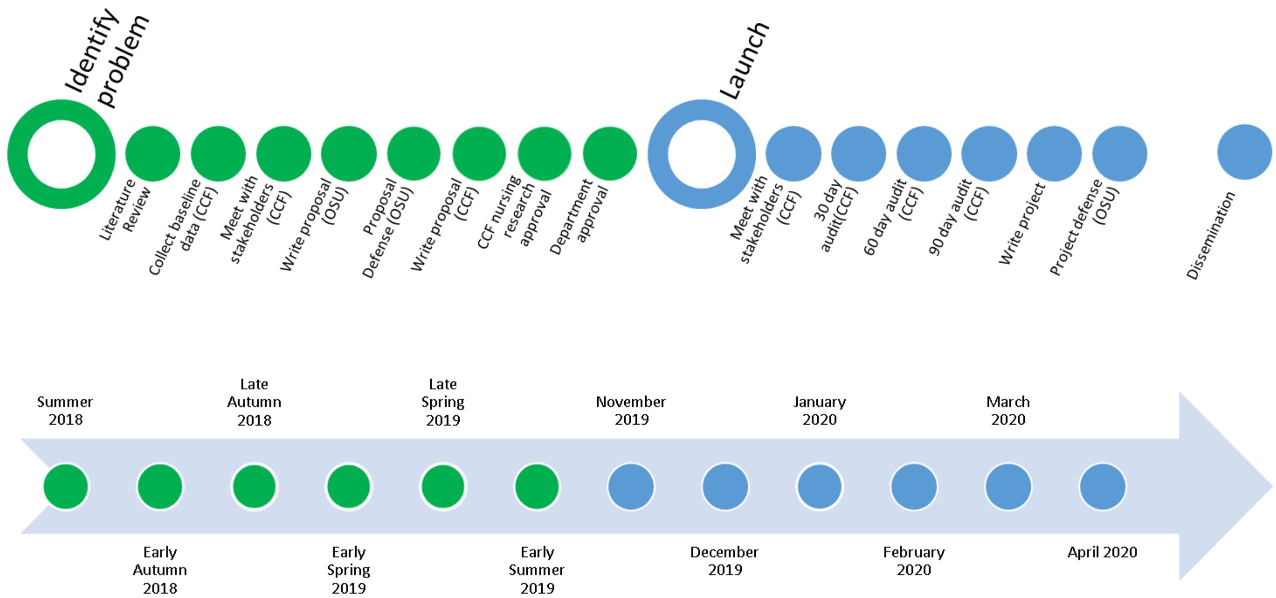
The financial cost of this project was anticipated to be minimal. The vaccines are stocked in the department, the personnel were in place, and meeting/educational materials were in electronic format, eliminating the need for printing costs. The greatest expense by far was the mandatory fee charged by the organization's Nursing Research Office, which covers the time of a senior nurse researcher for guidance as well as IRB submission.

Table 5: Proposed budget of QI project

QI project element	Cost charged to project
Provider time to order vaccine	$0 (already SOC)
MA time to administer vaccine(s)	$0 (already SOC)
ITD analyst time	$0 (included in department duties)
Influenza vaccine	$0 (already routinely stocked)
PCV-13 vaccine	$0 (already routinely stocked)
PPSV-23 vaccine	$0 (already routinely stocked)
Whiteboards	$40
Nursing Research Office Fee	$500
Launch meeting materials	$0 (PowerPoint presentation)
Total	$540

The timeline for this project spanned approximately 18 months from identification of the clinical problem to completion and write up of the project.

Figure 5: Timeline of QI project



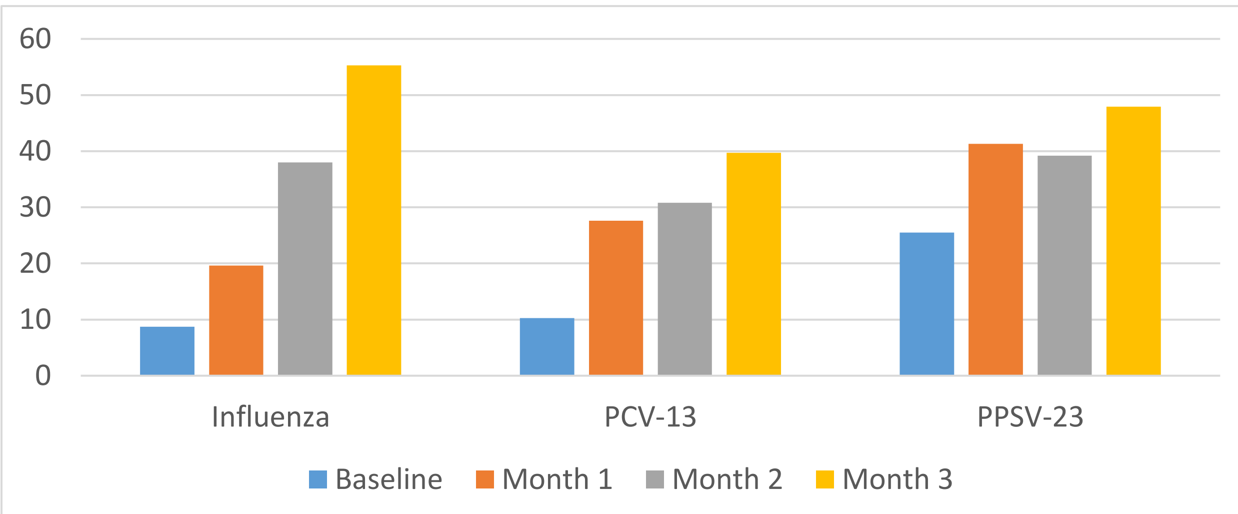
Section Four: Findings

Results/Outcome

The objective of this QI project was to improve percentages of documented vaccination in a particular subpopulation of patients. In order to determine whether or not the objective was met, the EMR was queried at baseline and predetermined time points after project launch. The analysis consisted of a simple comparison between pre and post intervention documented vaccination rates.

This project endeavored to answer the clinical practice problem statement: In adult patients on immunosuppressive medications, how do prepopulated orders attached to care gap alerts in the EMR and optimization of workflow using a centralized notification board affect levels of vaccination coverage? The answer is that during the intervention period, levels of documented vaccination increased. The four, eight, and 12 week data are included in Figure 6 and show that compared to baseline, documented influenza, PCV13, and PPSV23 vaccination increased by 46.6%, 29.4%, and 22.4%, respectively.

Figure 6: Percent of patients up to date on vaccinations



Limitations

Similar to other QI projects that used multiple interventions (Chow & Shojania, 2017; S. Garg et al., 2018; Harris et al., 2015; Parker et al., 2013; Sheth et al., 2017), the design of this project made it impossible to determine how much of each intervention contributed to the outcomes. What can be learned from this is that multi-component approach is important to optimizing results in this type of QI project.

Other factors beyond the interventions may have influenced the outcomes: the emergence of covid-19, a novel coronavirus, which may have increased awareness of respiratory illness, leading to an increased demand for influenza and pneumococcal vaccines by consumers; a severe influenza season, leading to more demand for vaccinations from patients; unavailability of

PCV13 vaccine for one week in January due to supply issues; launch of a statewide vaccination database, making incorporation of outside records easier than during the baseline data gathering period; MA turnover within the department; and the creation of workgroup "pods" within the department leading to increased interaction between prescribers and MAs.

One of the potential barriers identified prior to project launch was provider confusion regarding vaccine scheduled. This barrier was not addressed as part of the project, however, independently and during the project time period, exam room signage reminding providers about pneumococcal vaccinations was installed throughout the department.

Section Five: Recommendations and implications for practice

Project Summary, Discussion and Conclusions

This project used a team approach, orders attached to a care gap alert, and a new workflow process to increase documented vaccination in an immunosuppressed population. The increases seen were substantial and comparable to similar projects (Bays et al., 2016; S. Garg et al., 2016, 2018; Goodson et al., 2018; Sheth et al., 2017). Although vaccination rates did not reach goals established by Healthy People 2020, the project was still successful in that any increase equates to increased protection for the targeted population.

Implications for Practice

In 2005, the American Association of Colleges of Nursing created a task force to develop expectations surrounding the Doctor of Nursing Practice (DNP) curriculum. One year later the task force issued a report which outlined eight essentials of doctoral education for advanced nursing practice. These essentials "address the foundational competencies that are core to all advanced practice nursing roles" and cover a wide range of topics including technology, leadership, scholarship, collaboration, and others (American Association of Colleges of Nursing, 2006). Of the eight essentials, the two most relevant to this project are Essential II (Organizational and System Leadership for Quality Improvement and Systems Thinking) and Essential VII (Clinical Prevention and Population Health for Improving the Nation's Health). The relevance of Essential II stems from the fact that it specifically includes quality improvement as an avenue to increase patient safety as well as the mandate to ensure accountability for the safety of specific patient populations (American Association of Colleges of Nursing, 2006). The specific patient population in this case was immunocompromised adults, and patient safety was increased via protection from vaccine-preventable illnesses. Essential VIII broadens the scope of Essential II, in this case recognizing that increasing vaccination rates in any individual, in this case adult rheumatology patients, protects not just the person getting the vaccine but also increases the chances of achieving herd immunity, therefore protecting greater populations.

The satisfaction of two essentials for DNP practice reflects the rationale for continuation and possible expansion of the QI project. The interventions that led to an increase in vaccination rates are simple and cost very little, if anything, to maintain. Care gap alerts (with attached orders) are incorporated into the EMR and the white boards are now part of everyday use in the department. Although the specific team that worked on this project has no plans to meet regularly, other projects using the team approach, such as a vaccine reconciliation project and an EMR optimization project, have already been launched using the same model that was used for this project.

Improving vaccination rates satisfies much of the mission statement of the health care system in which this project took place ("To provide better care of the sick, investigation in their problems and further education of those who serve"). Although not research or an "investigation" into patients' problems, this project did result in better care of the sick partly through further education of rheumatology caregivers. Therefore the continuation of the project is reasonable and aligns with the framework of the larger hospital system. Future phases incorporating the human papilloma virus (HPV) and/or shingles vaccines will need to involve specialists who see patients in the appropriate age groups. The HPV group might have a better chance for success if physicians, APPs, nurses and MAs from the pediatric rheumatology department were invited to participate, along with the lupus clinic in adult rheumatology since their patient population includes a large number of young women. In contrast, shingles vaccination is recommended for individuals 50 years of age and older, so including the metabolic bone group – which treats patients with osteoporosis – would make sense.

Identify methods for dissemination

Immunosuppression is not unique to rheumatology. Many of the immunosuppressant medications used to treat rheumatic diseases are also approved for non-rheumatic autoimmune diseases; it follows that patients being treated for these conditions are just as vulnerable vaccine-preventable infections as rheumatology patients. Since this QI project proved to be successful, the author will offer to present the results at grand rounds in other departments such as dermatology, gastroenterology, neurology, and oncology. Although only a local-level effort, the impact could prove to be large given the size of the healthcare system and the numbers of patients treated.

As evidenced by the number of abstracts involving vaccine research at the ACR annual meetings over the last decade, immunization of patients with IMIDs is a topic which generates much interest among providers. Submitting an abstract to this meeting is also a possible method of dissemination of the results of this project. The ACR has a sub-organization called the Association of Rheumatology Professionals which includes social workers, psychologists, physical therapists, occupational therapists, basic scientists, nurses, pharmacists, nurse practitioners, and physician assistants. Accepted abstracts are displayed in one hall, ensuring they are available to all meeting attendees, making this dissemination method very impactful. By reaching all members of the health care team the authors will be able to catch the attention of anyone interested in improving rates of vaccination coverage in rheumatology patients.

Another possibility for dissemination is a poster or oral presentation at the Rheumatology Nurses Society or Rheumatology Advanced Practice Providers annual meetings. These meetings attract a more focused audience so would not reach as wide a group as a poster at the ACR, but presenting at these venues would still be impactful as many nurses and advanced practice providers may feel more comfortable approaching the author with questions at a meeting focused on their specialties.

Finally, submission to a journal such as Arthritis Care & Research or the Journal of Rheumatology would be another way to reach an audience interested in improving rates of vaccination coverage in immunosuppressed patients.

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Appendix A: Evaluation Table of Articles								
Citation	Design/Methods	Sample/Setting	Major Variables	Outcome Measurement	Data Analysis	Findings	LoE	Quality of Evidence
Garg (2018). The Journal of Rheumatology, 1656-1662	Multifaceted QI; pre-intervention surveys; pre-visit planning, day-of-visit planning, weekly review of data, monthly feedback sessions; EMR-generated reminders.	SLE patients, adult rheumatology, Emory University; 25 weeks	Vaccination rates PCV13, PPSV23, PCV13+PPSV23	Pre- and post-intervention vaccination rates	Vaccination rates, refusal rate, pneumococcal pneumonia-related hospitalization.	PCV13 2 → 39%, PPSV23 8→ 56%, combination 10 → 59%. Hospitalization 3.6 → 2.2%.	VI	Excellent
Baker (2016). The Journal of Rheumatology, 1030-1037	System-level intervention including multiple QI strategies. Electronic reminders with linked order sets, audit & feedback, patient outreach.	RA patients, adult rheumatology, Northwestern Medical Group; 12 months. N=1255.	PCV13, PPSV23, flu, HZ vaccination rates	Pre- and post-intervention vaccination rates.	EMR vaccination rates, refusal rates (PCV13, PPSV23, HZ); self-reported flu vaccination rates from a random sample of RA patients.	PCV13/PPSV23 29→46%; flu 79→78%; zoster 2→4%.	VI	Excellent except flu, which was self-reported.
Karr (2016). Ochsner Journal, 90-95	QI project to determine perceived barriers and improve process; order set in EMR.	IBD providers, adult gastroenterology, Ochsner Clinic; 2 months. N=13.	HAV, HBV, HPV, meningococcus, MMR, PCV13, PPSV23, TDaP, HZ, flu vaccination rates	Provider satisfaction with order set.	Qualitative report of survey results.	6 of 10 respondents reported an increase in vaccinations due to order set.	VI	Fair; pre- and post-surveys differed.

Citation	Design/Methods	Sample/Setting	Major Variables	Outcome Measurement	Data Analysis	Findings	LoE	Quality of Evidence
Desai (2013). Arthritis & Rheumatism, 39-47	QI project using paper reminder form generated from data in EMR.	Adult rheumatology patients receiving IS medications at 5 outpatient clinics; 38 months. N=3,717.	Vaccination rates for patients of providers who received intervention vs providers who didn't.	Patients UTD with pneumococcal vaccination	Pneumococcal vaccination rates.	% of patients UTD with pneumococcal vaccination 68→80% (intervention) vs 52→52% (control).	VI	Excellent
Ledwich (2009). Arthritis & Rhematism, 1505-1510	QI project using BPA in EMR.	Adult rheumatology patients receiving IS medications at 2 academic settings; 3 months.	PCV13, PPSV23, flu vaccination rate change at each site and between the two sites (site 1 physician based model, site 2 nurse based model).	Pre- and post-intervention vaccination rates.	Vaccination rates using chi-square test; demographics compared with Wilcoxon's analysis, chi-square test, Fisher's exact.	Flu vaccination 43→60% (site 1), 69→82% (site 2). Pneumococcal vaccination 15→39% (site 1), 47→57% (site 2).	VI	Excellent
Desai (2011). Rheumatology, 366-372	Measure and improve PPSV23 vaccination in patients on IS medications.	Adult patients receiving IS medications at Brigham & Women's Hospital outpatient rheumatology clinic; 24 months.	PPSV23 vaccination status. Additional data included age, race, gender, diagnosis.	Percentage of patients up to date with PPSV23, both generally and at initiation of IS medication.	Descriptive analysis	54% of patients on IS medication UTD on vaccination. 45% of patients newly started on IS medication UTD.	VI	Excellent except for data gap (IV medications)
Sheth (2017). The Journal of Rheumatology, 11-17	QI project to improve HZ vaccination using Intervention: BPA in EMR, modified clinic workflow; provider, staff, patient education; physician feedback and assessment.	Adult patients with RA at 13 UPMC rheumatology outpatient clinics; 12 months	HZ vaccine administration, prescription, deferred, declined.	Pre- and post-intervention vaccination rates.	Number of vaccinations or prescriptions for vaccinations given per total number of eligible patients with RA.	Vaccination 10→52%; vaccination + documentation 28→73%.	VI	Moderate; 42% of BPAs dismissed by physician. If included post-vax rate would have been 25% (not 52%).

Citation	Design/Methods	Sample/Setting	Major Variables	Outcome Measurement	Data Analysis	Findings	LoE	Quality of Evidence
Harris (2015). Pediatrics, e680-e686	QI project to improve pneumococcal vaccination using provider education, posted algorithm, pre-visit planning, written reminders.	Patients >2 years old at Children's Hospital of Wisconsin rheumatology clinic who either had SLE or were on IS medications; 12 months.	PCV13 and PPV23 rates stratified by diagnosis (JIA, SLE, and other)	Pre- and post-intervention vaccination rates.	# pts receiving PCV13/PPSV23 (numerator), # eligible patients (denominator). Results: baseline cohort and all patients after baseline.	PCV13 5 to 10% → 46 to 56%. PPSV23 5 to 16% → 25 to 46%.	VI	Excellent
Parker (2013). Inflammatory Bowel Disease, 1809-1814	QI project to increase flu and PPSV23 vaccination in immunosuppressed patients with IBD using PDSA. Interventions: paper update form for patients, offer vaccines in clinic.	Adult immunosuppressed IBD patients at the Dartmouth-Hitchcock IBD center.	Flu vaccination and PPSV23 rates.	Proportion of patients who received flu vaccination and PPSV23 previously compared with during the intervention.	Self-reported baseline vaccination rates. Flu vaccination and PPSV23 rates.	Flu vaccine 54→81%. PPSV23 31→54%.	VI	Very good; self-report of prior vaccination not confirmed.
Chow (2017). The Journal of Rheumatology, 1304-1310	QI project to increase flu vax in pts with IMIDs. Interventions: standardization of documentation, patient information, reminders to pharmacists on DMARD prescriptions.	Adult immunosuppressed patients at Sunnybrook Health Sciences Center.	Flu vaccination rates.	Proportion of patients who received intervention materials; proportion of patients who received flu vaccine.	Number of patients receiving vaccine (numerator), number of eligible patients (denominator)	Flu vaccine 40→65%	VI	Excellent

Abbreviations: BPA: best practice alert; EMR: electronic medical record; flu: influenza; HAV: hepatitis A virus; HBV: hepatitis B virus, HPV: human papilloma virus; HZ: Herpes zoster; IBD: inflammatory bowel disease; IS: immunosuppressive; IV: intravenous; JIA: juvenile idiopathic arthritis; LoE: level of evidence; MMR: measles, mumps, rubells; PCV13 pneumococcal conjugate vaccine; PDSA: plan do study act; PPSV23 pneumococcal polysaccharide vaccine; RA: rheumatoid arthritis; SLE: Systemic Lupus Erythematosus; TDaP: tetanus, diphtheria, acellular pertussis; QI: Quality Improvement

Appendix B: Synthesis Table of Articles

	Garg 2018	Baker 2016	Karr 2016	Desai 2013	Ledwich 2009	Desai 2011	Sheth 2017	Harris 2015	Parker 2013	Chow 2017
Rheum specific	✓	✓		✓	✓	✓	✓	✓		✓
Pneumonia	✓	✓	✓	✓	✓	✓		✓	✓	
Flu		✓	✓		✓				✓	✓
Intervention:										
Process change				✓		✓	✓	✓	✓	✓
EMR	✓	✓	✓		✓	✓	✓			
Team approach	✓						✓	✓	✓	✓
Highest % Improvement	49	17	N/A	12	24	N/A	42	21	27	25

Abbreviations: Rheum: rheumatology; Pneumonia: pneumonia vaccine (either PPSV23, PCV13, or both); Flu: influenza vaccine; EMR: electronic medical record.

Appendix C: Synthesis Table of ACR Abstracts

	Swee 2018	Goodson 2018	Aguirre 2017	O'Brien 2017	Ostrowski 2016	Garg 2016	Bays 2016	Bays 2015	Margaretten 2015	Bussey 2014	Schoenfeld 2014	Dudley 2014	Desai 2012
Vaccine	P	P	P	P	HZ	P	P	P	P	P	HZ	P	P
PDSA	✓						✓	✓	✓				
Intervention:													
Process change	✓	✓	✓			✓	✓	✓	✓			✓	
EMR				✓			✓	✓	✓		✓	✓	
Team approach	✓					✓	✓		✓			✓	
Highest % Improvement	18	39	84	15	12	48	40	57	72	18	17	30	12

Abbreviations: P: pneumonia vaccine (either PPSV23, PCV13, or both); HZ: herpes zoster vaccine; EMR: electronic medical record.

Appendix D: New Idea Scorecard: Improving Vaccination Coverage in Immunosuppressed Rheumatology Patients (Fraser, 2019)

	Relative Advantage	**Simplicity**	**Compatibility**	**Trialability**	**Observability**
Provider uses CGA					
Whiteboard (provider use)					
Whiteboard (MA use)					
Documentation					
ITD builds way for VIS to print in AVS					

Definitions:

Relative Advantage – the degree to which an innovation is perceived as better than the idea it supersedes

Simplicity – the degree to which an innovation is perceived as simple to understand and use

Compatibility – the degree to which an innovation is perceived as being consistent with the existing values, experiences, beliefs, and needs of potential adopters

Trialability – the degree to which an innovation can be tested on a small scale

Observability – the degree to which the use of an innovation and the results it produces are visible to those who should consider it

How to Use the Scorecard

- The exercise is done as a table exercise with people sitting at tables.
- Write the name of a specific change/innovation in the box at the left.
- Have each person independently rate the change from the “spread target” point of view. Use a 1–5 scale:
  1 — change is very weak relative to this attribute
  3 — change is okay relative to this attribute
  5 — change is very strong relative to this attribute
- After each table has had a chance to evaluate the change, have a report out and group discussion of how the changes were rated in relation to each of the attributes. Pay particular attention to: (1) any item where there are significant differences in scoring among the group (e.g., 2s and 5s on the same item); and (2) scores of 1 or 2 for any of the items.
- Use these discussions to plan how to overcome barriers that are identified and develop an action plan for addressing these barriers.

Teaching point is that each change differs on how easily it is likely to spread. Some may require specific communication messages or specific actions that a team can take to make it more likely to spread (e.g., make sure the test is visible and testable by others, simplify the instructions on how to do the change).

Appendix E: Percent of patients up to date on vaccinations 9/1/17 – 8/31/18 (by medication)

	PCV13	PPSV23	Flu
Abatacept	12.87	25.74	14.85
Adalimumab	6.01	17.84	7.95
Anakinra	7.27	14.55	3.64
Azathioprine	11.63	32.3	7.49
Belimumab	9.52	38.1	4.76
Certolizumab	12.5	18.75	6.25
Cyclophosphamide	13.89	16.67	8.33
Etanercept	6.59	10.85	4.65
Golimumab	2.27	9.09	4.55
Infliximab	18.18	43.8	19.83
Leflunomide	12.57	25.44	14.04
Methotrexate	12.26	24.47	11.67
Mycophenolate	12.05	35	9.77
Rituximab	13.68	32.42	11.58
Sarilumab	20	60	20
Secukinumab	3.17	26.98	4.76
Tocilizumab	7.69	17.31	8.65
Tofacitinib	1.8	18.92	2.7
Ustekinumab	11.11	16.67	0

Appendix F: Literature Search Results

Wateska, A.R., Nowalk, M.P., Lin, C.J., Harrison, L.H., Schaffner, W., Zimmerman, R.K., Smith, K.J.	An intervention to improve pneumococcal vaccination uptake in high risk 50-64 year olds vs. expanded age-based recommendations: an exploratory cost-effectiveness analysis	(2019) Human Vaccines and Immunotherapeutics, 15 (4), pp. 863-872.	NO	Financial info
Austin, B., Morgan, H.	Improving Human Papillomavirus Vaccine Uptake in the Family Practice Setting	(2019) Journal for Nurse Practitioners,	NO	Distance intervention, web-based, toolkits
Garg, S., Tsagaris, K., Cozmuta, R., Lipson, A.	Improving the combination pneumococcal vaccination rate in systemic lupus erythematosus patients at an adult rheumatology practice	(2018) Journal of Rheumatology, 45 (12), pp. 1656-1662	YES	
Baker, D.W., Brown, T., Lee, J.Y., Ozanich, A., Liss, D.T., Sandler, D.S., Ruderman, E.M.	A multifaceted intervention to improve influenza, pneumococcal, and herpes zoster vaccination among patients with rheumatoid arthritis	(2016) Journal of Rheumatology, 43 (6), pp. 1030-1037. Cited 7 times	YES	
Karr, J.R., Lu, J.J., Smith, R.B., Thomas, A.C.	Using computerized physician order entry to ensure appropriate vaccination of patients with inflammatory bowel disease	(2016) Ochsner Journal, 16 (1), pp. 90-95.	YES	
Sidani, M., Harris, J., Zoorob, R.J.	Adult immunization improvement in an underserved family medicine practice	(2015) Family Medicine and Community Health, 3 (2), pp. 2-7.	NO	Mostly patient-focused interventions
Jessop, A.B., Dumas, H., Moser, C.A.	Delivering Influenza Vaccine to High-Risk Adults: Subspecialty Physician Practices	(2013) American Journal of Medical Quality, 28 (3), pp. 232-237	NO	Survey of existing practices
Shojania KG, Jennings A, Mayhew A, Ramsay CR, Eccles MP, Grimshaw J	The effects of on-screen, point of care computer reminders on processes and outcomes of care	(2009) Cochrane Database of Systematic Reviews	YES	

Arditi C, Rège-Walther M, Durieux P, Burnand B	Computer-generated reminders delivered on paper to healthcare professionals: effects on professional practice and healthcare outcomes	(2017) Cochrane Database of Systematic Reviews	YES	
Gagliardi AMZ, Andriolo BNG, Torloni MR, Soares BGO	Vaccines for preventing herpes zoster in older adults	(2016) Cochrane Database of Systematic Reviews	NO	
Moberley S, Holden J, Tatham DP, Andrews RM	Vaccines for preventing pneumococcal infection in adults	(2013) Cochrane Database of Systematic Reviews	NO	
Jacobson Vann JC, Jacobson RM, Coyne-Beasley T, Asafu-Adjei JK, Szilagyi PG	Patient reminder and recall interventions to improve immunization rates	(2018) Cochrane Database of Systematic Reviews	NO	Patient focused
Demicheli V, Jefferson T, Di Pietrantonj C, Ferroni E, Thorning S, Thomas RE, Rivetti A	Vaccines for preventing influenza in the elderly	(2018) Cochrane Database of Systematic Reviews	NO	
Bitterman R, Eliakim-Raz N, Vinograd I, Zalmanovici Trestioreanu A, Leibovici L, Paul M	Influenza vaccines in immunosuppressed adults with cancer	(2018) Cochrane Database of Systematic Reviews	NO	
Thomas RE, Lorenzetti DL	Interventions to increase influenza vaccination rates of those 60 years and older in the community	(2018) Cochrane Database of Systematic Reviews	YES	
Sandler DS, Ruderman EM, Brown T, Lee JY, Mixon A, Liss DT, Baker DW	Understanding vaccination rates and attitudes among patients with rheumatoid arthritis.	Am J Manag Care. 2016 Mar;22(3):161-7. PMID: 27023021	NO	pt self-reported data
Kirchner E, Ruffing V	Barriers to Immunizations and Strategies to Enhance Immunization Rates in Adults with Autoimmune Inflammatory Diseases.	Rheum Dis Clin North Am. 2017 Feb;43(1):15-26. doi: 10.1016/j.rdc.2016.09.004. Review. PMID: 27890171	NO	historical review

Jones KB, Gren LH, Backman R	Improving pediatric immunization rates: description of a resident-led clinical continuous quality improvement project.	Fam Med. 2014 Sep;46(8):631-5. PMID: 25163043	NO	Focus on teaching residents QI; pediatrics
Gurvits GE, Lan G, Tan A, Weissman A	Vaccination practices in patients with inflammatory bowel disease among general internal medicine physicians in the USA.	Postgrad Med J. 2017 Jun;93(1100):333-337. doi: 10.1136/postgradmedj-2016-134266. Epub 2016 Oct 12. PMID: 27733673	NO	Survey of physician practices/knowledge
Maldonado AQ, Johnson D, Trofe-Clark J	Barriers to vaccination in renal transplant recipients.	Transpl Infect Dis. 2017 Oct;19(5). doi: 10.1111/tid.12749. Epub 2017 Sep 4. PMID: 28714222	NO	Identifies barriers, no interventions
Whitaker JA, von Itzstein MS, Poland GA	Strategies to maximize influenza vaccine impact in older adults.	Vaccine. 2018 Sep 25;36(40):5940-5948. doi: 10.1016/j.vaccine.2018.08.040. Epub 2018 Aug 25. Review. PMID: 30153995	NO	Study compared efficacy of different flu vaccines
Garg M, Mufti N, Palmore TN, Hasni SA	Recommendations and barriers to vaccination in systemic lupus erythematosus.	Autoimmun Rev. 2018 Oct;17(10):990-1001. doi: 10.1016/j.autrev.2018.04.006. Epub 2018 Aug 11. Review. PMID: 30103044	NO	Summary of recommendations
Lawson EF, Trupin L, Yelin EH, Yazdany J.	Reasons for failure to receive pneumococcal and influenza vaccinations among immunosuppressed patients with systemic lupus erythematosus.	Semin Arthritis Rheum. 2015 Jun;44(6):666-71. doi: 10.1016/j.semarthrit.2015.01.002. Epub 2015 Jan 22. PMID: 25701500	NO	Patient survey
Laniosz V, Lehman JS, Poland GA, Wetter DA	Literature-based immunization recommendations for patients requiring immunosuppressive medications for autoimmune bullous dermatoses.	Int J Dermatol. 2016 Jun;55(6):599-607. doi: 10.1111/ijd.13140. Epub 2015 Dec 29. Review. PMID: 26711431	NO	General recommendations only

Olshefski RS, Bibart M, Frost R, Wood E, Hampl J, Mangum R, Ardura M, Guinipero T, Cripe TP.	A multiyear quality improvement project to increase influenza vaccination in a pediatric oncology population undergoing active therapy.	Pediatr Blood Cancer. 2018 Sep;65(9):e27268. doi: 10.1002/pbc.27268. Epub 2018 Jun 1. PMID: 29856533	YES	Patient education, provider education, communication of vaccine status.
Lester R, Lu Y, Tung J.	Survey of Immunization Practices in Patients With Inflammatory Bowel Disease Among Pediatric Gastroenterologists.	J Pediatr Gastroenterol Nutr. 2015 Jul;61(1):47-51. doi: 10.1097/MPG.0000000000000730. PMID: 25611033	NO	Survey of physician practices/knowledge
Pickering LK, Baker CJ, Freed GL, Gall SA, Grogg SE, Poland GA, Rodewald LE, Schaffner W, Stinchfield P, Tan L, Zimmerman RK, Orenstein WA; Infectious Diseases Society of America	Immunization programs for infants, children, adolescents, and adults: clinical practice guidelines by the Infectious Diseases Society of America.	Clin Infect Dis. 2009 Sep 15;49(6):817-40. doi: 10.1086/605430. Erratum in: Clin Infect Dis. 2009 Nov 1;49(9):1465. PMID: 19659433	NO	Guidelines only
Wasan SK, Coukos JA, Farraye FA	Vaccinating the inflammatory bowel disease patient: deficiencies in gastroenterologists knowledge.	Inflamm Bowel Dis. 2011 Dec;17(12):2536-40. doi: 10.1002/ibd.21667. Epub 2011 Apr 28. PMID: 21538710	NO	Survey of physician practices/knowledge
Lehman JS, Murrell DF, Camilleri MJ, Kalaaji AN	Infection and infection prevention in patients treated with immunosuppressive medications for autoimmune bullous disorders.	Dermatol Clin. 2011 Oct;29(4):591-8. doi: 10.1016/j.det.2011.06.021. PMID: 21925003	NO	Patient education; non-specific
Brenneman AE, Essary AC	Quality improvement: tobacco use, diabetes, and vaccines.	JAAPA. 2012 May;25(5):21-2. PMID: 22712144	NO	Call for QI, no study or recommendations
Geer JJ	Increasing Vaccination Rates in a Pediatric Chronic Hemodialysis Unit.	Nephrol Nurs J. 2016 Jan-Feb;43(1):31-3, 37; quiz 34. PMID: 27025147	YES	QI, but HD patients

Nowalk MP, Zimmerman RK, Lin CJ, Reis EC, Huang HH, Moehling KK, Hannibal KM, Matambanadzo A, Shenouda EM, Allred NJ	Maintenance of Increased Childhood Influenza Vaccination Rates 1 Year After an Intervention in Primary Care Practices.	Acad Pediatr. 2016 Jan-Feb;16(1):57-63. doi: 10.1016/j.acap.2015.03.010. PMID: 26767508	NO	Focus on economically disadvantaged children
Trogstad L, Ung G, Hagerup-Jenssen M, Cappelen I, Haugen IL, Feiring B	The Norwegian immunisation register--SYSVAK.	Euro Surveill. 2012 Apr 19;17(16). pii: 20147. PMID: 22551462	NO	Description of national database
Heim JA, Huang H, Zabinsky ZB, Dickerson J, Wellner M, Astion M, Cruz D, Vincent J, Jack R	Design and implementation of a combined influenza immunization and tuberculosis screening campaign with simulation modelling.	J Eval Clin Pract. 2015 Aug;21(4):727-34. doi: 10.1111/jep.12377. Epub 2015 May 26. PMID: 26009843	NO	Efficiency study of HCW
Venkat A, Chan-Tompkins NH, Hegde GG, Chuirazzi DM, Hunter R, Szczesiul JM	Feasibility of integrating a clinical decision support tool into an existing computerized physician order entry system to increase seasonal influenza vaccination in the emergency department.	Vaccine. 2010 Aug 23;28(37):6058-64. doi: 10.1016/j.vaccine.2010.06.090. Epub 2010 Jul 8. PMID: 20620167	YES	
Gilkey MB, Moss JL, Roberts AJ, Dayton AM, Grimshaw AH, Brewer NT	Comparing in-person and webinar delivery of an immunization quality improvement program: a process evaluation of the adolescent AFIX trial.	Implement Sci. 2014 Feb 18;9:21. doi: 10.1186/1748-5908-9-21. PMID: 24533515	NO	Compares effectiveness of various teaching methods.
Cockman P, Dawson L, Mathur R, Hull S	Improving MMR vaccination rates: herd immunity is a realistic goal.	BMJ. 2011 Oct 4;343:d5703. doi: 10.1136/bmj.d5703. PMID: 21971162	NO	Financial incentives to practices in London
Cadena J, Prigmore T, Bowling J, Ayala BA, Kirkman L, Parekh A, Scepanski T, Patterson JE.	Improving influenza vaccination of healthcare workers by means of quality improvement tools.	Infect Control Hosp Epidemiol. 2011 Jun;32(6):616-8. doi: 10.1086/660198. PMID: 21558776	NO	Interventions not transferrable from employee health to outpatient care.
Dayton A	Improving quality of health care using the North Carolina Immunization Registry.	N C Med J. 2014 May-Jun;75(3):198-203. PMID: 24830495	NO	Data mining

Bruce A, Lau S, Reber T, Laverdiere L, Tompkins N	Efficacy of Flu Vaccination Mail-out Reminders in Pediatric Hematology Patients for Quality Improvement: Does Snail-Mail Still Work?	J Pediatr Hematol Oncol. 2018 Nov;40(8):629-630. doi: 10.1097/MPH.0000000000001195. PMID: 29697581	NO	Patient based intervention
Park NJ, Sklaroff LM, Gross-Schulman S, Hoang K, Tran H, Campa D, Scheib G, Guterman JJ	Innovative Strategies Designed to Improve Adult Pneumococcal Immunizations in Safety Net Patient-Centered Medical Homes.	Popul Health Manag. 2016 Aug;19(4):240-7. doi: 10.1089/pop.2015.0099. Epub 2016 Jan 29, PMID: 26824148	NO	Homeless population outreach
Swenson CJ, Appel A, Sheehan M, Hammer A, Fenner Z, Phibbs S, Harbrecht M, Main DS.	Using information technology to improve adult immunization delivery in an integrated urban health system.	Jt Comm J Qual Patient Saf. 2012 Jan;38(1):15-23. Jt Comm J Qual Patient Saf. 2012 Jan;38(1):15-23.PMID: 22324187	YES	
Brusaferro S, Londero C, Panariti M, Farneti F, Calligaris L, Coppola N, Gallo T, Iob A, Osquino I; Regional Group for Vaccination Improvement	Professional quality improvement project in vaccination services: results of a 5-year survey.	Eur J Public Health. 2010 Aug;20(4):449-51. doi: 10.1093/eurpub/ckp180. Epub 2009 Nov 5. PMID: 19892854	NO	Italy, local health authorities, not tranferrable
Desai SP, Lu B, Szent-Gyorgyi LE, Bogdanova AA, Turchin A, Weinblatt M, Coblyn J, Greenberg JO, Kachalia A, Solomon DH.	Increasing pneumococcal vaccination for immunosuppressed patients: a cluster quality improvement trial.	Arthritis Rheum. 2013 Jan;65(1):39-47. doi: 10.1002/art.37716. PMID: 23044506	YES	
Lin CJ, Zimmerman RK, Smith KJ	Cost-effectiveness of pneumococcal and influenza vaccination standing order programs.	Am J Manag Care. 2013 Jan 1;19(1):e30-7. PMID: 23379777	YES	Cost-effectiveness only
Robinson EF, Cooley C, Schleyer AM, Schreuder AB, Onstad S, Chang J, Marti A, Minton-Foltz P, Goss JR	Using an electronic medical record tool to improve pneumococcal screening and vaccination rates for older patients admitted with community-acquired pneumonia.	Jt Comm J Qual Patient Saf. 2011 Sep;37(9):418-24, 385. PMID: 21995258	YES	

Rees S, Stevens L, Drayton J, Engledow N, Sanders J	Improving inpatient pneumococcal and influenza vaccination rates.	J Nurs Care Qual. 2011 Oct-Dec;26(4):358-63. doi: 10.1097/NCQ.0b013e31821fb6bb. PMID: 21577146	NO	Specifically inpatient intervention
Smith JG, Metzger NL	Evaluation of pneumococcal vaccination rates after vaccine protocol changes and nurse education in a tertiary care teaching hospital.	J Manag Care Pharm. 2011 Nov;17(9):701-8. PMID: 22050395	NO	Inpatient intervention
Kanter MH, Lindsay G, Bellows J, Chase A	Complete care at Kaiser Permanente: transforming chronic and preventive care.	Jt Comm J Qual Patient Saf. 2013 Nov;39(11):484-94. PMID: 24294676	NO	Immunizations only one small part of delivery system intervention
Bond TC, Patel PR, Krisher J, Sauls L, Deane J, Strott K, Karp S, McClellan W	Association of standing-order policies with vaccination rates in dialysis clinics: a US-based cross-sectional study.	Am J Kidney Dis. 2009 Jul;54(1):86-94. doi: 10.1053/j.ajkd.2008.12.038. Epub 2009 Apr 5. PMID: 19346041	NO	Survey of self-reported practices
Nemeth LS, Ornstein SM, Jenkins RG, Wessell AM, Nietert PJ	Implementing and evaluating electronic standing orders in primary care practice: a PPRNet study.	J Am Board Fam Med. 2012 Sep-Oct;25(5):594-604. doi: 10.3122/jabfm.2012.05.110214. PMID: 22956695	YES	
Nowalk MP, Tabbarah M, Hart JA, Fox DE, Raymund M, Wilson SA, Zimmerman RK; FM-PittNet Practice Based Research Network	Office manager and nurse perspectives on facilitators of adult immunization.	Am J Manag Care. 2009 Oct;15(10):755-60. PMID: 19845428	NO	Survey of current practice
Terasaki J, Singh G, Zhang W, Wagner P, Sharma G	Using EMR to improve compliance with clinical practice guidelines for management of stable COPD.	Respir Med. 2015 Nov;109(11):1423-9. doi: 10.1016/j.rmed.2015.10.003. Epub 2015 Oct 9. PMID: 26475055	NO	Specific to COPD; flu immunization only one of many guidelines.

Nace DA, Perera S, Handler SM, Muder R, Hoffman EL	Increasing influenza and pneumococcal immunization rates in a nursing home network.	J Am Med Dir Assoc. 2011 Nov;12(9):678-84. doi: 10.1016/j.jamda.2010.05.002. Epub 2010 Oct 2. PMID: 21450182	NO	Multi-site information intervention in long term care; not transferrable to outpatient clinic.
Yancey AM, Jundt AB, Nelson KJ.	Pneumococcal vaccination process improvement in an acute care setting.	Qual Saf Health Care. 2010 Dec;19(6):e61. doi: 10.1136/qshc.2008.028746. Epub 2010 Aug 25, PMID: 20798068	YES	Pneumovax; QI; PDSA
Ledwich LJ, Harrington TM, Ayoub WT, Sartorius JA, Newman ED	Improved influenza and pneumococcal vaccination in rheumatology patients taking immunosuppressants using an electronic health record best practice alert.	Arthritis Rheum. 2009 Nov 15;61(11):1505-10. doi: 10.1002/art.24873. PMID: 19877088	YES	
Yazdany J, Tonner C, Trupin L, Panopalis P, Gillis JZ, Hersh AO, Julian LJ, Katz PP, Criswell LA, Yelin EH	Provision of preventive health care in systemic lupus erythematosus: data from a large observational cohort study.	Arthritis Res Ther. 2010;12(3):R84. doi: 10.1186/ar3011. Epub 2010 May 12. PMID: 20462444	NO	Baseline data only
Lynch JR, Frankovich E, Tetrick CA, Howard AD	Improving influenza vaccination in dialysis facilities.	Am J Med Qual. 2010 Nov-Dec;25(6):416-28. doi: 10.1177/1062860610367957. Epub 2010 May 14. PMID: 20472818	NO	Tracking tool for established patients; not applicable for clinic w/many new patients.
Bond TC, Patel PR, Krisher J, Sauls L, Deane J, Strott K, McClellan W	A group-randomized evaluation of a quality improvement intervention to improve influenza vaccination rates in dialysis centers.	Am J Kidney Dis. 2011 Feb;57(2):283-90. doi: 10.1053/j.ajkd.2010.09.019. Epub 2010 Dec 13. PMID: 21146267	NO	Intervention is educational seminars

van Lieshout J, Wensing M, Grol R	Improvement of primary care for patients with chronic heart failure: a pilot study.	BMC Health Serv Res. 2010 Jan 8;10:8. doi: 10.1186/1472-6963-10-8. PMID: 20064198	NO	Not a vaccine study
Bounthavong M, Christopher ML, Mendes MA, Foster EB, Johns ST, Lim L, Rubin LM, Patel JJ, Stewart AG	Measuring patient satisfaction in the pharmacy specialty immunization clinic: a pharmacist-run Immunization Clinic at the Veterans Affairs San Diego Healthcare System.	Int J Pharm Pract. 2010 Apr;18(2):100-7. PMID: 20441119	NO	Patient satisfaction survey
Marsteller JA, Hsiao CJ, Underwood WS, Woodward P, Barr MS	A simple intervention promoting patient safety improvements in small internal medicine practices.	Qual Prim Care. 2010;18(5):307-16. PMID: 21114911	NO	Handling (not administering) vaccines
Roberts DH, Gilmartin GS, Neeman N, Schulze JE, Cannistraro S, Ngo LH, Aronson MD, Weiss JW	Design and measurement of quality improvement indicators in ambulatory pulmonary care: creating a "culture of quality" in an academic pulmonary division.	Chest. 2009 Oct;136(4):1134-1140. doi: 10.1378/chest.09-0619. PMID: 19809055	YES	
Souza NM, Sebaldt RJ, Mackay JA, Prorok JC, Weise-Kelly L, Navarro T, Wilczynski NL, Haynes RB; CCDSS Systematic Review Team	Computerized clinical decision support systems for primary preventive care: a decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes.	Implement Sci. 2011 Aug 3;6:87. doi: 10.1186/1748-5908-6-87. Review. PMID: 21824381	NO	Literature review
Desai SP, Turchin A, Szent-Gyorgyi LE, Weinblatt M, Coblyn J, Solomon DH, Kachalia A	Routinely measuring and reporting pneumococcal vaccination among immunosuppressed rheumatology outpatients: the first step in improving quality.	Rheumatology (Oxford). 2011 Feb;50(2):366-72. doi: 10.1093/rheumatology/keq297. Epub 2010 Oct 24. PMID: 20974614	YES	Validates measurement of problem
Bernstein HH, Monty M, Yang P, Cohen A	Increasing Tdap Coverage Among Postpartum Women: A Quality Improvement Intervention.	. PMID: 28179484 Pediatrics. 2017 Mar;139(3). pii: e20160607. doi: 10.1542/peds.2016-0607. Epub 2017 Feb 8	NO	Inpatient intervention

Lehmann CE, Brady RC, Battley RO, Huggins JL	Adolescent Vaccination Strategies: Interventions to Increase Coverage.	Paediatr Drugs. 2016 Aug;18(4):273-85. doi: 10.1007/s40272-016-0177-1. Review. PMID: 27146296	NO	Review of existing strategies; HPV only; adolescents
Sheth H, Moreland L, Peterson H, Aggarwal R	Improvement in Herpes Zoster Vaccination in Patients with Rheumatoid Arthritis: A Quality Improvement Project.	J Rheumatol. 2017 Jan;44(1):11-17. doi: 10.3899/jrheum.160179. Epub 2016 Nov 15. PMID: 28042124	YES	
Williams DL, Wheeler CS, Lawrence M, Hall SS, Hagensee M	Louisiana Physicians Are Increasing HPV Vaccination Rates.	J La State Med Soc. 2017 May-Jun;169(3):63-67. Epub 2017 Jun 23. PMID: 28644153	NO	Survey of existing practices
Nemerofsky SL, Akingboye B, Ferguson C, Africa D	Sustained Improvement in Administration of the Hepatitis B Vaccine Birth Dose: A Quality Improvement Initiative.	Am J Med Qual. 2018 May/Jun;33(3):313-320. doi: 10.1177/1062860617732635. Epub 2017 Oct 5. PMID: 28978224	NO	Inpatient intervention; newborns
Zweigoron RT, Roberts JR, Levin M, Chia J, Ebeling M, Binns HJ	Influence of Office Systems on Pediatric Vaccination Rates.	Clin Pediatr (Phila). 2017 Mar;56(3):231-237. doi: 10.1177/0009922816650396. Epub 2016 Jul 12. PMID: 27242379	NO	Survey of existing practices; pediatrics
Bowen ME, Bhat D, Fish J, Moran B, Howell-Stampley T, Kirk L, Persell SD, Halm EA	Improving Performance on Preventive Health Quality Measures Using Clinical Decision Support to Capture Care Done Elsewhere and Patient Exceptions.	Am J Med Qual. 2018 May/Jun;33(3):237-245. doi: 10.1177/1062860617732830. Epub 2017 Oct 14. PMID: 29034685	NO	Study of capturing outside info
Grivas PD, Devata S, Khoriaty R, Boonstra PS, Ruch J, McDonnell K, Hernandez-Aya L, Wilfong J, Smerage J, Ison MG, Eisenberg JNS, Silveira M, Cooney KA, Worden FP	Low-Cost Intervention to Increase Influenza Vaccination Rate at a Comprehensive Cancer Center.	J Cancer Educ. 2017 Dec;32(4):871-877. doi: 10.1007/s13187-016-1017-2. PMID: 27055536	YES	Provider and patient reminders
Tan LLJ	A review of the key factors to improve adult immunization coverage rates: What can the clinician do?	Vaccine. 2018 Aug 28;36(36):5373-5378. doi: 10.1016/j.vaccine.2017.07.050. Epub 2017 Aug 10. Review. PMID: 28803713	NO	Policy review

Clark RC, Jackson J, Hodges D, Gilliam B, Lane J	Improving pneumococcal immunization rates in an ambulatory setting.	J Nurs Care Qual. 2015 Jul-Sep;30(3):205-11. doi: 10.1097/NCQ.0000000000000110. PMID: 25565463	YES	
Jones KB, Spain C, Wright H, Gren LH	Improving Immunizations in Children: A Clinical Break-even Analysis.	Clin Med Res. 2015 Jun;13(2):51-7. doi: 10.3121/cmr.2014.1234. Epub 2014 Nov 7. PMID: 25380614	NO	Pediatrics, patient focused interventions
Hawk M, Nowalk MP, Moehling KK, Pavlik V, Raviotta JM, Brown AE, Zimmerman RK, Ricci EM	Using a Mixed Methods Approach to Examine Practice Characteristics Associated With Implementation of an Adult Immunization Intervention Using the 4 Pillars Practice Transformation Program.	J Healthc Qual. 2017 May/Jun;39(3):153-167. doi: 10.1097/JHQ.0000000000000071. PMID: 28166113	NO	Survey of existing practices
McLean HQ, VanWormer JJ, Chow BDW, Birchmeier B, Vickers E, DeVries E, Meyer J, Moore J, McNeil MM, Stokley S, Gee J, Belongia EA	Improving Human Papillomavirus Vaccine Use in an Integrated Health System: Impact of a Provider and Staff Intervention.	J Adolesc Health. 2017 Aug;61(2):252-258. doi: 10.1016/j.jadohealth.2017.02.019. Epub 2017 Apr 24. PMID: 28462786	NO	Provider education only; patient focused intervention
Anderson LJ, Shekelle P, Keeler E, Uscher-Pines L, Shanman R, Morton S, Aliyev G, Nuckols TK	The Cost of Interventions to Increase Influenza Vaccination: A Systematic Review.	Am J Prev Med. 2018 Feb;54(2):299-315. doi: 10.1016/j.amepre.2017.11.010. Epub 2018 Jan 18. PMID: 29362167	NO	Financial survey; review
Soon R, Sung S, Cruz MR, Chen JJ, Hiraoka M	Improving Human Papillomavirus (HPV) Vaccination in the Postpartum Setting.	J Community Health. 2017 Feb;42(1):66-71. doi: 10.1007/s10900-016-0230-6. PMID: 27476162	YES	
Dumit EM, Novillo-Ortiz D, Contreras M, Velandia M, Danovaro-Holliday MC.	The use of eHealth with immunizations: An overview of systematic reviews.	Vaccine. 2018 Dec 18;36(52):7923-7928. doi: 10.1016/j.vaccine.2018.06.076. Epub 2018 Jul 6. Review. PMID: 29983255	NO	Patient intervention
Harris JG, Maletta KI, Ren B, Olson JC	Improving Pneumococcal Vaccination in Pediatric Rheumatology Patients.	Pediatrics. 2015 Sep;136(3):e681-6	YES	

Dawson R, Lemmon K, Trivedi NJ, Hansen S.	Improving human papilloma virus vaccination rates throughout military treatment facilities.	Vaccine. 2018 Mar 7;36(11):1361-1367. doi: 10.1016/j.vaccine.2018.02.007. Epub 2018 Feb 9. PMID: 29433899	NO	Provider education session only
Freedman JL, Reilly AF, Powell SC, Bailey LC	Quality improvement initiative to increase influenza vaccination in pediatric cancer patients.	Pediatrics. 2015 Feb;135(2):e540-6. doi: 10.1542/peds.2014-0943. Epub 2015 Jan 12. PMID: 25583919	YES	
Clark RC, Carter KF, Jackson J, Hodges D	Audit and Feedback: A Quality Improvement Study to Increase Pneumococcal Vaccination Rates.	J Nurs Care Qual. 2018 Jul/Sep;33(3):291-296. doi: 10.1097/NCQ.0000000000000289. PMID: 29790866	YES	
Jiang C, Whitmore-Sisco L, Gaur AH, Adderson EE; Tdap Working Group	A quality improvement initiative to increase Tdap (tetanus, diphtheria, acellular pertussis) vaccination coverage among direct health care providers at a children's hospital.	Vaccine. 2018 Jan 4;36(2):214-219. doi: 10.1016/j.vaccine.2017.11.071. Epub 2017 Dec 6. PMID: 29217370	NO	Intervention specific to employee health; not generalizable to outpatient clinic
Perkins RB, Zisblatt L, Legler A, Trucks E, Hanchate A, Gorin SS.	Effectiveness of a provider-focused intervention to improve HPV vaccination rates in boys and girls.	Vaccine. 2015 Feb 25;33(9):1223-9. doi: 10.1016/j.vaccine.2014.11.021. Epub 2014 Nov 24. PMID: 25448095	NO	Incentivized
Sobota AE, Kavanagh PL, Adams WG, McClure E, Farrell D, Sprinz PG	Improvement in influenza vaccination rates in a pediatric sickle cell disease clinic.	Pediatr Blood Cancer. 2015 Apr;62(4):654-7. doi: 10.1002/pbc.25390. Epub 2014 Dec 24. PMID: 25545967	YES	
Malone K, Clark S, Palmer JA, Lopez S, Pradhan M, Furth S, Kim J, Fisher B, Laskin B	A quality improvement initiative to increase pneumococcal vaccination coverage among children after kidney transplant.	Pediatr Transplant. 2016 Sep;20(6):783-9. doi: 10.1111/petr.12742. Epub 2016 Jun 22. PMID: 27334506	NO	Pediatric age-based algorithm
Loskutova N, Smail C, Webster B, Ajayi K, Wood J, Carroll J	Missed opportunities for improving practice performance in adult immunizations: a meta-narrative review of the literature.	BMC Fam Pract. 2017 Dec 22;18(1):108. doi: 10.1186/s12875-017-0694-1. Review. PMID: 29272999	NO	Research terminology validation

Peterson S, Taylor R, Sawyer M, Nagy P, Paine L, Berenholtz S, Miller R, Petty B.	The power of involving house staff in quality improvement: an interdisciplinary house staff-driven vaccination initiative.	Am J Med Qual. 2015 Jul-Aug;30(4):323-7. doi: 10.1177/1062860614532682. Epub 2014 May 9. PMID: 24814939	NO	Interdepartment competition; inpatient only
Chung RJ, Walter EB, Kemper AR, Dayton A.	Keen on teen vaccines: improvement of adolescent vaccine coverage in rural North Carolina.	J Adolesc Health. 2015 May;56(5 Suppl):S14-6. doi: 10.1016/j.jadohealth.2014.10.272. PMID: 25863548	NO	Patient interventions
Parker S, Chambers White L, Spangler C, Rosenblum J, Sweeney S, Homan E, Bensen SP, Levy LC, Dragnev MC, Moskalenko-Locke K, Rich P, Siegel CA	A quality improvement project significantly increased the vaccination rate for immunosuppressed patients with IBD.	Inflamm Bowel Dis. 2013 Aug;19(9):1809-14. doi: 10.1097/MIB.0b013e31828c8512. PMID: 23714677	YES	
Szilagyi PG, Serwint JR, Humiston SG, Rand CM, Schaffer S, Vincelli P, Dhepyasuwan N, Blumkin A, Albertin C, Curtis CR	Effect of provider prompts on adolescent immunization rates: a randomized trial.	Acad Pediatr. 2015 Mar-Apr;15(2):149-57. doi: 10.1016/j.acap.2014.10.006. PMID: 25748976	YES	
Chow SL, Shojania KG.	"Rheum to Improve": Quality Improvement in Outpatient Rheumatology.	J Rheumatol. 2017 Sep;44(9):1304-1310. doi: 10.3899/jrheum.161053. Epub 2017 Jul 1. Review. PMID: 28668805	YES	Excellent overview of QI
Wong PKK, Bagga H, Barrett C, Hanrahan P, Johnson D, Katrib A, Leder K, Marabani M, Pentony P, Riordan J, White R, Young L	A practical approach to vaccination of patients with autoimmune inflammatory rheumatic diseases in Australia.	Intern Med J. 2017 May;47(5):491-500. doi: 10.1111/imj.13371. Review. PMID: 28101910	NO	Recommendation for travelers
Kung YM	A quality improvement project to increase influenza vaccination in healthcare personnel at a university health center.	J Am Assoc Nurse Pract. 2014 Mar;26(3):148-54. doi: 10.1002/2327-6924.12060. Epub 2013 Aug 19. PMID: 24170432	NO	Survey of patient barriers

Delacruz W, Terrazzino S, Osswald M, Payne C, Haney B	Implementing a Multidisciplinary Approach to Enhance Compliance With Guideline-Recommended Prechemotherapy Pneumococcal Vaccination in a Military-Based Medical Oncology Practice.	J Oncol Pract. 2017 Nov;13(11):e966-e971. doi: 10.1200/JOP.2016.015602. Epub 2017 Sep 6. PMID: 28876159	YES	
Fu LY, Zook K, Gingold JA, Gillespie CW, Briccetti C, Cora-Bramble D, Joseph JG, Haimowitz R, Moon RY.	Strategies for Improving Vaccine Delivery: A Cluster-Randomized Trial.	Pediatrics. 2016 Jun;137(6). pii: e20154603. doi: 10.1542/peds.2015-4603. Epub 2016 May 10. PMID: 27244859	NO	Pay for performance vs virtual QI
Parry G, Coly A, Goldmann D, Rowe AK, Chattu V, Logiudice D, Rabrenovic M, Nambiar B	Practical recommendations for the evaluation of improvement initiatives.	Int J Qual Health Care. 2018 Apr 20;30(suppl_1):29-36. doi: 10.1093/intqhc/mzy021. PMID: 29447410	NO	Wrong topic
Rand CM, Schaffer SJ, Dhepyasuwan N, Blumkin A, Albertin C, Serwint JR, Darden PM, Humiston SG, Mann KJ, Stratbucker W, Szilagyi PG	Provider Communication, Prompts, and Feedback to Improve HPV Vaccination Rates in Resident Clinics.	Pediatrics. 2018 Apr;141(4). pii: e20170498. doi: 10.1542/peds.2017-0498. Epub 2018 Mar 14. PMID: 29540572	NO	Education only, no EMR, no process change
Bloland P, MacNeil A	Defining & assessing the quality, usability, and utilization of immunization data.	BMC Public Health. 2019 Apr 4;19(1):380. doi: 10.1186/s12889-019-6709-1. PMID: 30947703	NO	Interesting but more for statisticians
Bottino CJ, Cox JE, Kahlon PS, Samuels RC	Improving immunization rates in a hospital-based primary care practice.	Pediatrics. 2014 Apr;133(4):e1047-54. doi: 10.1542/peds.2013-2494. Epub 2014 Mar 24. PMID: 24664096	NO	Medical home-based
Shultz CG, Malouin JM, Green LA, Plegue M, Greenberg GM	A Systems Approach to Improving Tdap Immunization Within 5 Community-Based Family Practice Settings: Working Differently (and Better) by Transforming the Structure and Process of Care.	Am J Public Health. 2015 Oct;105(10):1990-7. doi: 10.2105/AJPH.2015.302739. Epub 2015 Aug 13. PMID: 26270283	YES	

Gingold JA, Briccetti C, Zook K, Gillespie CW, Gubernick RS, Moon RY, Fu LY	Context Matters: Practitioner Perspectives on Immunization Delivery Quality Improvement Efforts.	Clin Pediatr (Phila). 2016 Aug;55(9):825-37. doi: 10.1177/0009922815625874. Epub 2016 Jan 6. PMID: 26743455	NO	Study is about acceptance of QI
Fu LY, Weissman M, McLaren R, Thomas C, Campbell J, Mbafor J, Doshi U, Cora-Bramble D.	Improving the quality of immunization delivery to an at-risk population: a comprehensive approach.	Pediatrics. 2012 Feb;129(2):e496-503. doi: 10.1542/peds.2010-3610. Epub 2012 Jan 9. PMID: 22232306	NO	Peds-specific
Kim JM, Rivera M, Persing N, Bundy DG, Psoter KJ, Ghazarian SR, Miller MR, Solomon BS	Electronic Immunization Alerts and Spillover Effects on Other Preventive Care.	Clin Pediatr (Phila). 2017 Aug;56(9):811-820. doi: 10.1177/0009922817715935. PMID: 28720032	NO	N/A
Montejo L, Richesson R, Padilla BI, Zychowicz ME, Hambley C	Increasing Influenza Immunization Rates Among Retail Employees: An Evidence-Based Approach.	Workplace Health Saf. 2017 Sep;65(9):424-429. doi: 10.1177/2165079916686591. Epub 2017 Apr 20. PMID: 28427302	NO	Patient-focused interventions
Lau D, Hu J, Majumdar SR, Storie DA, Rees SE, Johnson JA	Interventions to improve influenza and pneumococcal vaccination rates among community-dwelling adults: a systematic review and meta-analysis.	Ann Fam Med. 2012 Nov-Dec;10(6):538-46. doi: 10.1370/afm.1405. Review. PMID: 23149531	YES	
Bundy DG, Persing NM, Solomon BS, King TM, Murakami PN, Thompson RE, Engineer LD, Lehmann CU, Miller MR	Improving immunization delivery using an electronic health record: the ImmProve project.	Acad Pediatr. 2013 Sep-Oct;13(5):458-65. doi: 10.1016/j.acap.2013.03.004. Epub 2013 Mar 14. PMID: 23726754	YES	
Kellogg KC, Gainer LA, Allen AS, O'Sullivan T, Singer SJ	An intraorganizational model for developing and spreading quality improvement innovations.	Health Care Manage Rev. 2017 Oct/Dec;42(4):292-302. doi: 10.1097/HMR.0000000000000122. PMID: 27428788	YES	For dissemination stage of project
Gannon M, Qaseem A, Snooks Q, Snow V	Improving adult immunization practices using a team approach in the primary care setting.	Am J Public Health. 2012 Jul;102(7):e46-52. doi: 10.2105/AJPH.2012.300665. Epub 2012 May 17. PMID: 22594743	YES	